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# OUTLOOK ON AGRICULTURE

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53
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# OUTLOOK ON AGRICULTURE

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PAGE

130 *Editorial: Approach to Pesticide Discovery*

131 *Machine Milking*
F. H. DODD, B.Sc., Ph.D., and P. A. CLOUGH, B.Sc.

145 *The Toxic Action of Herbicides*
E. K. WOODFORD, M.Sc., Ph.D., D.I.C.

155 *Detailed Soil Maps for Experimental Farms*
A. J. LOW, M.Sc., M.Sc. (Agric.), A.R.I.C.

159 *Methods of Insecticide Application against the Desert Locust*
R. C. RAINEY, Ph.D., A.R.C.S.

162 *Mistblowing in Orchards in the Netherlands*
DR. IR. E. W. B. VAN DEN MUIJZENBERG

165 *Book Reviews*

166 *Abstracts*

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# APPROACH TO PESTICIDE DISCOVERY

Within the past few years there has been a decided change in approach to the discovery of chemicals for pest and disease control. It is reflected in the subjects of papers in technical journals, as may be seen in our article on the toxic action of herbicides, and we devote this page to an explanation of what has happened.

Not so very long ago the provision of pesticides attracted little attention from research workers. Some inorganic chemicals and natural materials of limited efficacy were available, and there seemed little prospect of getting anything better until the appearance of a few organic materials stimulated leading chemical firms in the 1930s to undertake speculative work in the synthesis of pesticides. Astonishing success rewarded these efforts. DDT, γ-BHC, parathion, schradan, MCPA, 2,4-D and 2,4,5-T were all found between 1938 and 1945, and these discoveries, announced almost simultaneously at the end of the war, created the hope among scientists that progress could at last be made by leaps in place of steps.

Inspired by these results, biochemists rushed to the work of "screening" or evaluating chemicals for toxicity. The general idea was that because chemical structure and biological activity are closely related it should be easy, once a chemical of reasonable activity had been found, to change constituent molecular groups and synthesize materials of greater value. Starting compounds would be selected by the routine testing of numerous chemicals against typical organisms; and promising materials, modified if need be in structure, would graduate through stricter tests in the laboratory and field until they qualified for the market. It was an attractive approach.

Unfortunately the method did not come up to expectations. Structural modification sometimes proved little better than intelligent guesswork; for biological activity could not always be expressed in chemical terms, physical factors were often important, and reactions in living tissues could confound prediction. Moreover, random screening was far from quick or cheap in getting results, and out of tens of thousands of chemicals tested comparatively few valuable materials emerged. One American report estimates a success-rate of 1 in 1800, an expenditure of well over a million dollars from initial screening to marketing of a successful product, and the elapse of 5–10 years before any return could be expected. The general conclusion is that screening is unlikely to be profitable unless it is restricted to particularly promising fields.

While this work was going on the new materials were being put into effective use, and for years the main concern was the end in view—death of the organism; but it gradually became clear that we must learn more about the mechanism of toxic action and related problems of great complexity. For a toxicant to bring about a biological effect it must get on to the pest or plant, be taken up and transported to the site of action, and act. All are problems of interrelation: they involve not merely the effect of the chemical on the organism but—a much-neglected factor—the effect of the organism on the chemical; and only by understanding them can we explain phenomena met in the field and be in a position to design products to overcome them.

As Dr. Woodford shows, we know next to nothing about the ways in which selective herbicides kill plants. Death will occur if any vital function of the plant, such as respiration or photosynthesis, is completely inhibited, and often it is not known which of these has been affected by a lethal chemical. Yet each life process depends on a series of reactions taking place in a regular sequence, and if a chemical acts against any one of these, by inhibiting an enzyme or competing with an essential metabolite or in any other way, the chain is cut and the plant will die. It would obviously aid our search if we knew exactly where each chemical hits plant, insect or fungus to disturb a normal function or to kill.

Many other problems call for studies of a fundamental nature. For example, the specificity of insecticides, acquired resistance and detoxification await explanation of what goes on in the insect body. Materials already present in the organism or plant profoundly affect the stability and activity of introduced chemicals, converting some compounds of little or no toxicity into active forms and metabolizing others to inactive degradation products. Such factors are of great importance, yet the nature of the substances involved is largely unknown.

In short, we lack the biochemical background that would enable us to understand life processes in host and parasite and so reveal physiological causes of death and possible ways of bringing this about. Scientists now believe that the best prospects of advance lie in knowing more about biological fundamentals, and they have turned to study them in the hope of finding better leads to the synthesis of pesticides and new pathways for speculation and research.

# MACHINE MILKING

F. H. Dodd and P. A. Clough
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*Although the milking machine was introduced many years ago it did not become widely used until economic conditions from 1940 on favoured its rapid adoption by farmers. In this article the development is discussed in its more scientific aspects. Principles on which the use of the machine should be based are outlined, and an account is given of recent research work, showing how the properties of the machine can affect milking efficiency.*

The importance of the milking machine in the farm economy of Great Britain is best seen from the fact that of the 140,000 dairy farmers about 100,000 milk by machine. This situation has only existed for a few years, and the adoption of milking machines shows an interesting and peculiar pattern. By 1900 a milking machine had been evolved which was fundamentally the same as those used today, and yet by 1938 less than 10% of cows were milked by machine. Since the beginning of the second world war there has been a rapid change (Figure 1), and now over 80% of cows are machine milked. Obviously the acceptance of the milking machine by farmers did not follow the technical development of the machine, but was governed by economic conditions and a natural reluctance to change from hand milking. This reluctance was evident in the 1930s, when, although labour was relatively plentiful, the economic situation was such that—at least for the larger farmer—the intelligent use of machines could have lowered the cost of production to meet the low price obtained for milk. This was demonstrated in a striking way in the farming of Mr. A. J. Hosier, who pioneered the use of portable milking bails with large extensively managed herds in this country.

In the last ten years it has been impossible to find the labour to hand-milk cows, and farmers have been forced to go over to machine milking. The rise in output per cow over this period suggests that the bias against machine milking previously shown by the farmer was largely unwarranted. The farmer's interest in machine milking is paralleled by that of the research worker. Up to 1940 no serious scientific study of machine milking was carried out, and work was confined almost entirely to development of types of machines to fit different farming systems.

Today, conditions are changing. The great advances of the last twenty years in our knowledge of the physiology of lactation, particularly of milk ejection, have made the scientific study of milking possible, and we can now outline the principles on which the use of the milking machine should be based. At the same time a start has been made in the study of machine milking, notably of the effect of varying the working properties of the machine on the efficiency of milking. The results of this work are already of practical value.

The object of this article is to review the development of the milking machine and research on its performance up to the present day, and to point to the way in which it may evolve in future.

## HISTORY OF MILKING MACHINES

Over the past hundred years many attempts have been made to produce a machine that would milk dairy cows. For the first half of this period virtually nothing was known of the physiology of milk secretion and milk ejection; but to develop a milking machine the only essential knowledge of the animal required is that the teat orifice is the valve retaining the milk within the udder, and this must have been evident from experience of hand milking. Thus, the need was to open the teat orifice without causing pain or inflicting damage to the udder.

In the early machines three main ways of opening the teat orifice were tried, but until 1900 none was generally accepted. The simplest of these was to insert a cannula or milking tube through the teat orifice and allow the milk to drain out, or be sucked out, by connecting the cannula to a source of vacuum. This method, which is still "discovered" every few years, needs no elaborate equipment; but no one has yet succeeded in preventing the high mastitis infection brought about by the transfer from cow to cow of pathogenic organisms on the milking tubes. Even with sterile tubes for each cow, pathogens on the skin of the teats will be pushed into the teat sinus when the tubes are fitted.

The second method of milking was to use ingenious devices known as "lactators." These simulated the action of hand milking in sealing off the teat sinus from the udder by exerting pressure at the base of the teat and then squeezing out the milk by further pressure down the side of the teat. They enjoyed a vogue for a few years, but were doomed to failure because of the difficulty of cleaning and the mechanical problems involved in producing a design suitable for all shapes and sizes of udders and teats.

The principle that was ultimately accepted relied on the application of a partial vacuum to the outside of the teat to open the orifice and withdraw milk, in much the same way as the calf obtains milk. The first machine of this type to gain any success was designed by Murchland of Ayrshire in 1889. It applied the relatively low partial vacuum of about 11 inches of mercury to the teats and was able to extract milk, but it was not practical because the breakdown of blood circulation in the tissues in the area subjected to the constant vacuum caused pain and discomfort to the cow and inhibited milk ejection.

To overcome this defect the principle of pulsation was introduced. The function of the pulsation was to relieve the teats at frequent short intervals from the force of the vacuum. In the Thistle machine (1895) pulsation was produced by rapid fluctuations of the pressure in the teat cup from 15 to 2 or 3 inches of mercury. This method of preventing discomfort, pain and injury was later adopted in the Lawrence-Kennedy milking machine (1897), which was the first to achieve international acceptance.

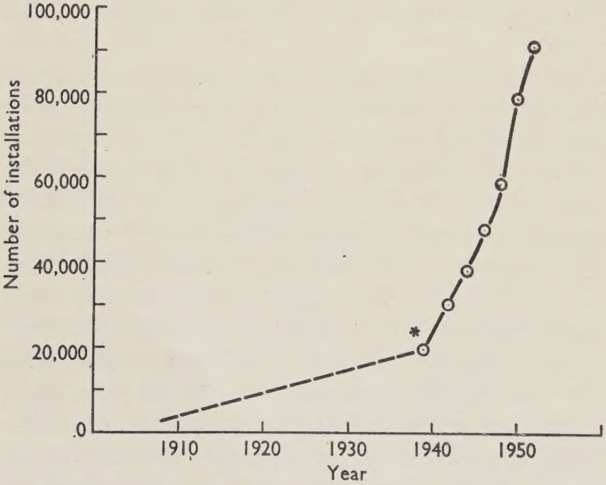


FIG. 1. Increase in the number of milking machine installations in Great Britain from the time when the double-action machine was invented. (Statistics are not available until 1942.) The asterisk indicates an estimated figure.

At this stage in the evolution of the milking machine the major difficulties had been overcome; all that now remained was to improve methods of applying the vacuum and the pulsation to the teats, and to discover the effects of variations in these factors on the efficiency of milking.

The main advance in this field was made by Gillies in Australia, who in 1903 modified the Lawrence-Kennedy machine and introduced the two-chamber teat cup. This was the first double-action milking machine, and from it nearly all present-day models are derived. With this design the teat is held in a teat-cup liner (i.e. a rubber tube) inside a metal teat cup. Pulsation causes the rhythmical expansion and collapse of the teat-cup liner during milking by alternately applying a partial vacuum and admitting atmospheric air to the space between the rubber liner and the teat-cup shell, while the inside of the liner is continuously subjected to the partial vacuum. The movement of the liner has a massaging effect on the teat and relieves the congestion of blood in the teat tissues, caused by the force of the partial vacuum when the liner is in the expanded or rest position.

There is no conclusive evidence as to the relative merits of single-action and double-action machines, but the former gradually lost favour, probably because, although simple, they milked more slowly.

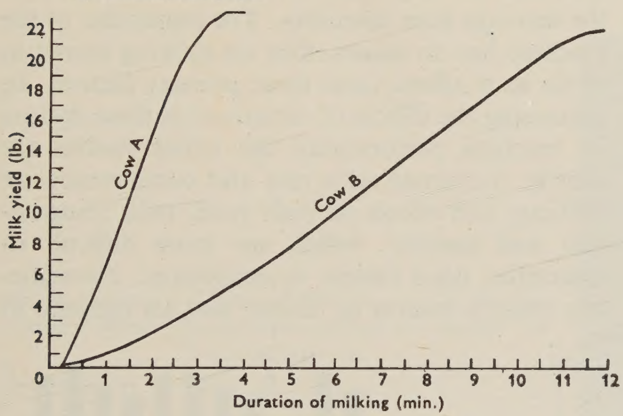
From the time when double-action machines were introduced there has been no major change in the principles of the milking machine. The arbitrary level of partial vacuum and the pulsation rates chosen in the early days have remained unaltered, and modifications in liner design and form of pulsation do not appear to have been the result of objective studies of the effects of these properties of the machine on milking. Equipment, however, has been devised for different systems of milk production, and a series of types is available. The probability that research work on milking machines was not considered worth while when economic conditions favoured the continuation of hand milking would explain the lack of information available at the outbreak of the second world war. Since then an increasing interest has been shown in milking machines and machine milking.

## MEASUREMENT OF MACHINE PERFORMANCE

In research to improve the milking machine two aspects of its performance have to be measured: mechanical efficiency in removing milk from the udder, and the effect on farm profits. While the second is ultimately the more important, it depends partly on the first and partly on the skill with which the machine is used. Only effectiveness of the machine in milking is dealt with here.

There can be no single measure of effectiveness of the machine for milking cows: effects on milk yield, milk composition, milking rate, incidence of mastitis, completeness of removal of milk and keeping quality of the milk produced must all be assessed. Measurement of some of these factors is relatively easy and has been developed for other purposes. For example, the measurement of lactation milk yield and the chemical composition of milk present no new problems. In order that research could be carried out on the effects of machines on milking rate, completeness of milking and mastitis incidence, new techniques have been evolved. Methods of measuring the rate at which milk is removed from the udder range from the simple system of suspending the milking bucket from a spring balance and recording the increase in weight with unit increase in time [13] (Figure 6) to the more complex type of electrical and electronic recorders [20]. All these methods give the same type of results, and examples of these are shown in two forms in Figure 2.

(*a*) Quantity/time graphs



(*b*) Rate/time graphs

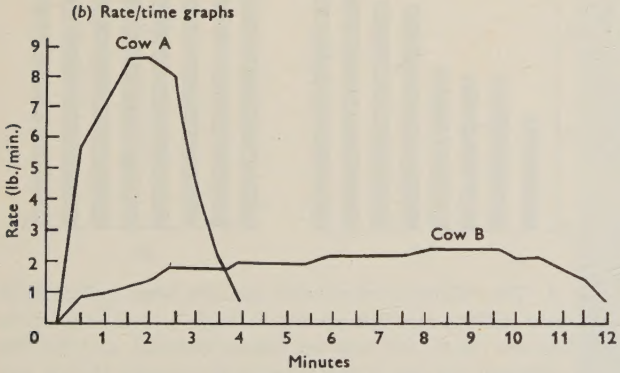


FIG. 2. The milking rate records of two cows, expressed as quantity/time and rate/time graphs. (Reproduced by permission of the editors of the *Journal of Dairy Research.*)

Because milking machines remove the last 5–10% of the milk yield very slowly, measurement of the amount removed by hand or by machine stripping, after the flow rate has fallen below an arbitrary limit, has been used to determine the completeness of milking. At the National Institute for Research in Dairying (N.I.R.D.) a rate of 0·3 lb. milk in 30 seconds has been used as this limit.

Measurement of the effects of milking on mastitis is of key importance, but it is greatly complicated by the long duration of the experiments, the number of cows needed and the heavy laboratory work, quite apart from the difficulties of controlling the extent to which each cow is exposed to bacterial infection. It is hoped that some of these troubles will be overcome by the use of special techniques now being tested. Methods have also been devised to measure the mechanical efficiency of the vacuum pumps, vacuum regulators, pulsators and other components of milking machine installations. These are not primarily concerned with the effect of the milking machine on the cow and are therefore not within the scope of this article.

### *Variation in Milking Rate*

Much information has been collected on normal variations in machine milking rate [9]. Variation is large between cows (coefficient of variation 35%) but is relatively small for individual cows from day to day (coefficient of variation 10%). Using a vacuum of 15 in. Hg with a pulsation rate of 50 cycles per minute and a pulsation ratio* of 1 : 1, milking rates within the range of 1·0 lb./min. to 12 lb./min. are found (Figure 3). Because of the marked differences in milking rate and milk yield between cows, the duration of milking will vary from below 3 min. to more than 15 min., and the individual cow will obviously take longer to milk when at the peak of lactation. Variations in milking rate with lactation stage and age are, to a large degree, a reflection of changes in yield; nearly all changes that occur are directly proportional to yield. The main exception is that the yield of strippings progressively increases from the first calving, the increase being particularly marked when the udder becomes divided or badly shaped.

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* For a definition of pulsation ratio see the second paragraph under "Pulsation," page 139.

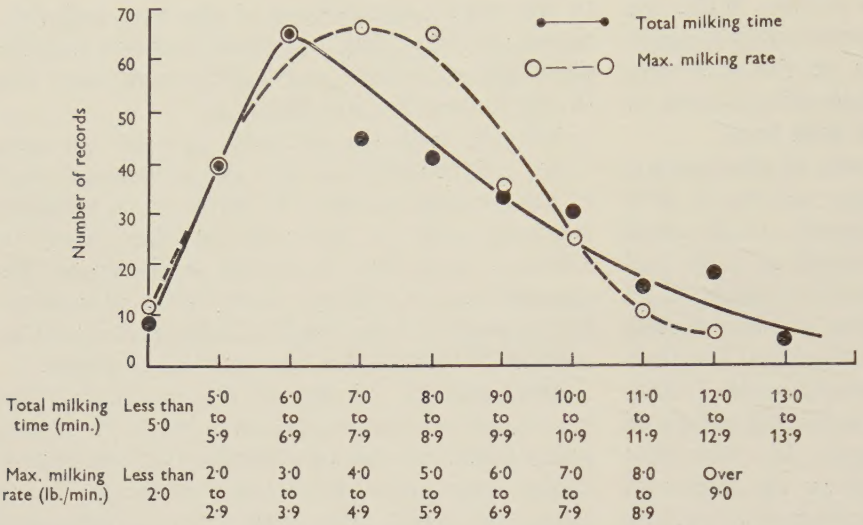


FIG. 3. The range and distribution of records of the total milking time and maximum milking rate collected from 326 cows.

Initial studies of the factors which control the rate of removal of milk from the udder indicate that variation in the effective size of the teat orifice during milking is mainly responsible for the wide differences in milking rate between cows [3]. From Figure 4 it will be seen that the milking rates of eight quarters showing large differences could be equalized by standardizing the teat-orifice size with a cannula. This is confirmed by the fact that there is a positive internal milk pressure in the udder sinus throughout the main part of milking, indicating that movement of milk within the udder, following ejection, is not normally a factor limiting milking rate.

Milk ejection is transitory, and so it is to be expected that milk yield will be related to milking rate: the faster a cow is milked, the greater the quantity of milk obtained. This has been clearly demonstrated on a number of occasions with hand-milked cows [1], and, even though experimental proof is lacking that a faster rate brought about by changes in machine milking conditions increases milk yield, there is no reason to believe that such increases will not occur. There is a further interesting aspect of this relationship. Within a herd the forces that the milking machine applies to the teat are the same for all cows, and therefore the differences in milking rate are due to physiological differences between cows. The obvious course was to determine whether slow milking cows give less milk than fast milkers. Initial investigations have demonstrated that there is a definite relationship. From records collected from 86 first-lactation animals it has been shown that the mean regression coefficient of lactation yield (gal.) and maximum milking rate (lb./min.) was 41·9 ± 11·7. On this basis a group of cows each with a maximum milking rate of 8 lb./min. could be expected to give an average of 160 gal. more per lactation than a group of cows each milking at 4·0 lb./min. No relationship between milking rate and fat percentage has been found, and that for the solids-not-fat content of milk is slightly but significantly negative [10] (Figure 13).

## MECHANICAL PROPERTIES OF THE MACHINE AND THEIR EFFECTS

The mechanical properties of the machine concerned with milking are the vacuum and the pulsation and the way these are applied to the teat in the teat-cup liner assembly. The remainder of the machine has no direct effect on milking except in so far as it affects these three primary factors. In measuring the effects of variations in these factors on machine performance the initial studies are usually concerned with rate and completeness of milking; and effects on milk yield, milk composition and mastitis, which are more difficult to determine, need further investigation. Nevertheless there is reason to believe that an increase in

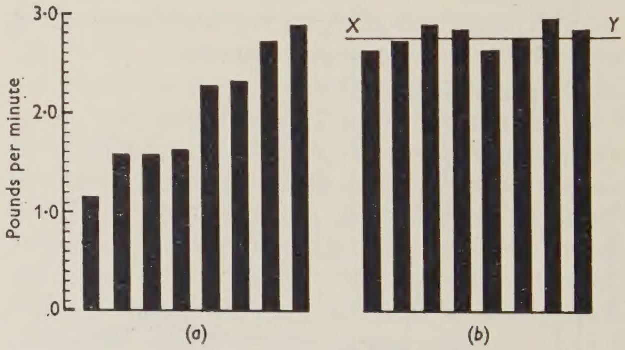
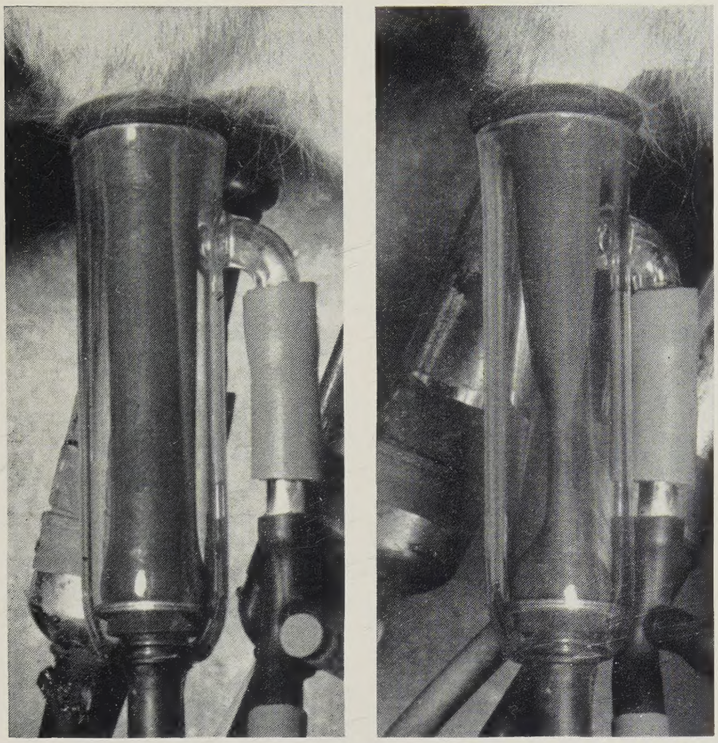


FIG. 4. The milking rates of eight quarters when milked by a standard milking machine (*a*) and through a cannula fitted in the teat (*b*). In (*b*) the rates are almost identical, and the line XY represents the rate of flow through the cannula when it was fitted to a reservoir of milk and operated at normal milking machine vacuum. (Reproduced by permission of the editors of the *Journal of Dairy Research*.)



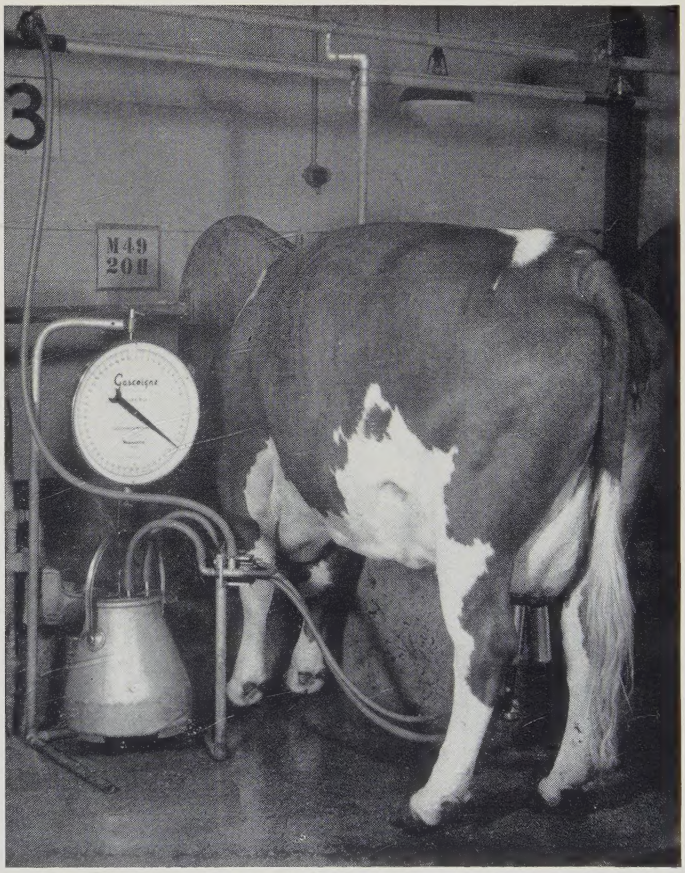
(*a*) (*b*)

Fig. 5. The two phases of pulsation photographed with a normal extruded liner working inside a glass teat cup.

(*a*) When milk flow is taking place with similar vacuum conditions on either side of the liner walls.

(*b*) Milk flow ceases when the atmospheric pressure in the pulsation chamber collapses the liner round the teat.

Fig. 6. Measuring the rate of milk flow into the machine during milking. The balance readings are recorded at 30-second intervals.



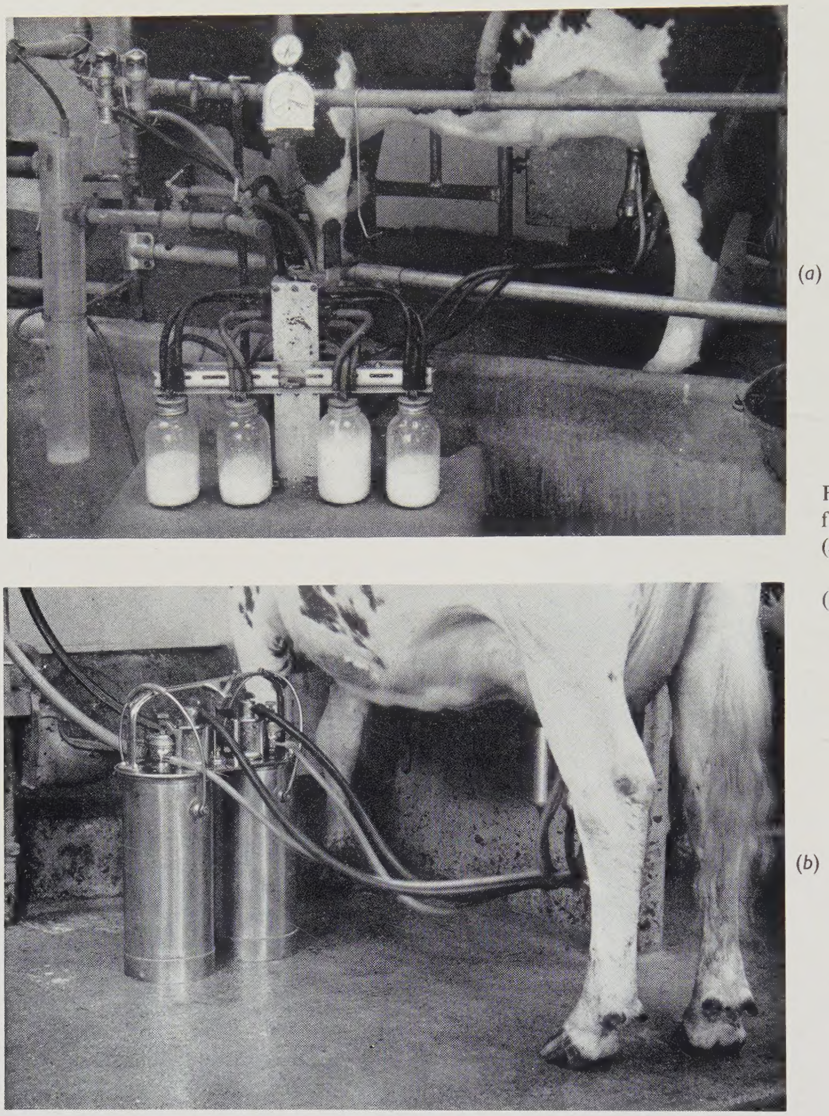


FIG. 7. Experimental milking machines used for "half-udder" milking.
(*a*) For use when a comparison of the rates of milking of different halves is needed.
(*b*) For use in milk yield and mastitis studies.

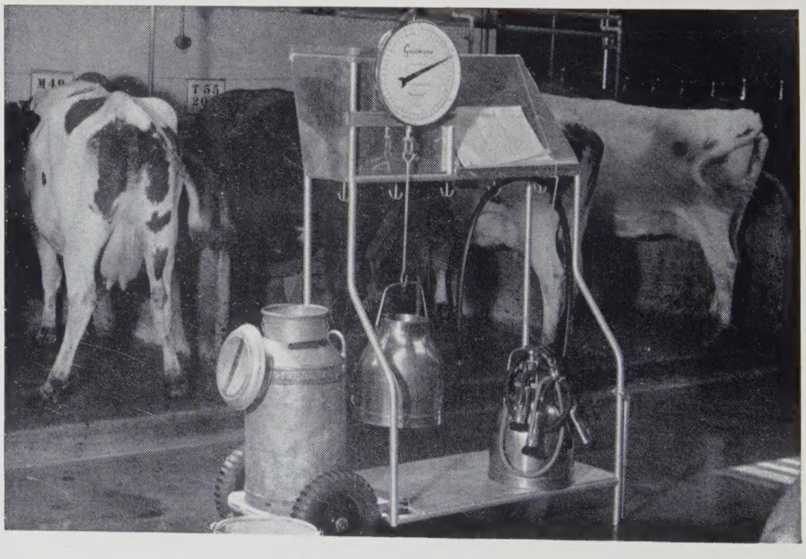
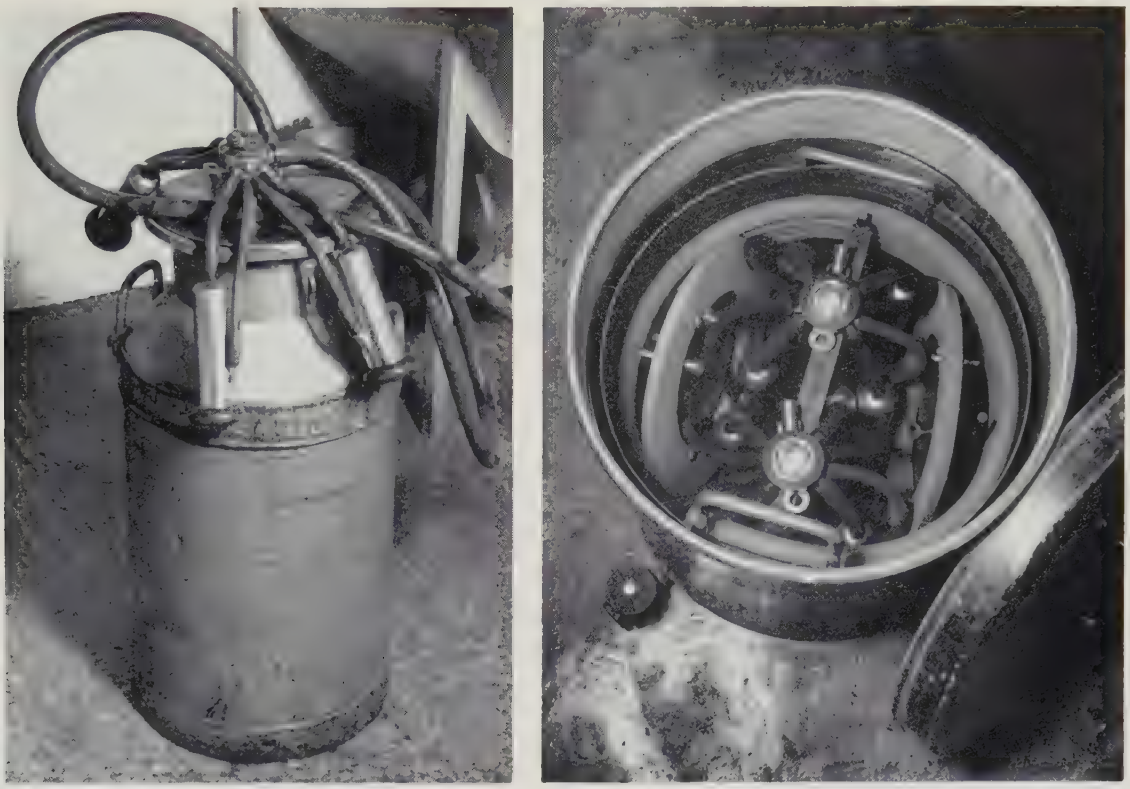


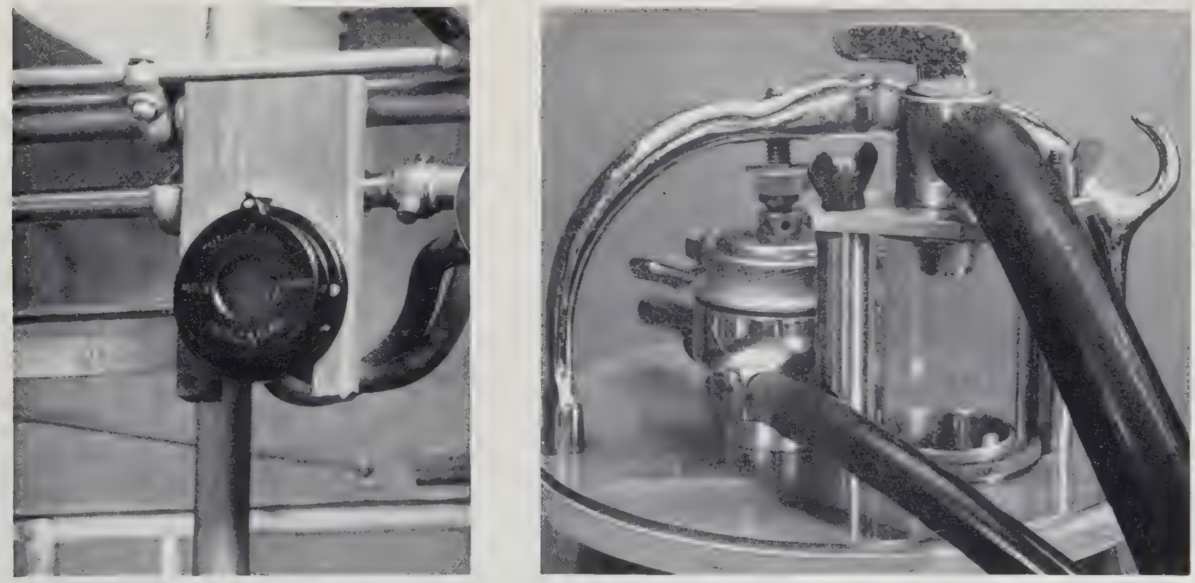
FIG. 8. A trolley suitable for use in cowsheds. With this type, which carries milk-recording and milk-collecting gear, walking is greatly reduced.



(a) (b)

FIG. 9. Immersion cleaning of milking machines.

(*a*) The simplified milking equipment assembled ready for milking.
(*b*) Milking equipment sufficient for a herd of up to 40 cows, stored in the cleaning and sterilizing solution.



(a) (b)

FIG. 10.

(*a*) Milk-flow indicator for use with pipeline milking developed at the Ruakura Research Station, New Zealand.
(*b*) Prototype sight glass developed at the N.I.R.D. for use with bucket milking machines.

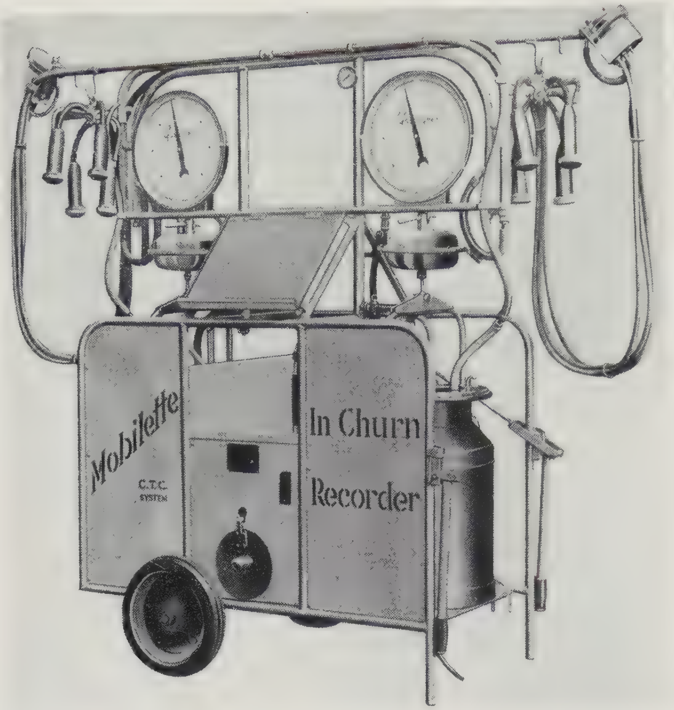


FIG. 11. A mobile milking machine for use in cowsheds. The trolley is fitted for direct-to-can milking with provision for milk recording. (Reproduced by permission of Gascoignes Ltd.)

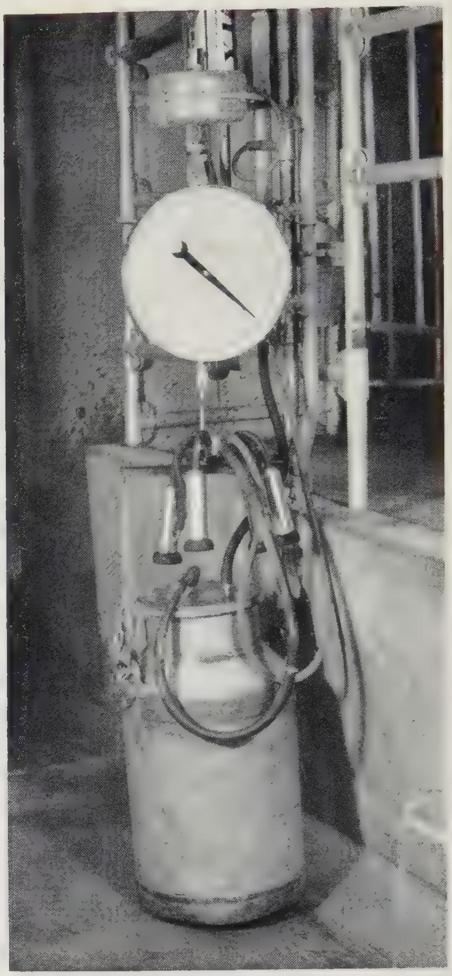


FIG. 12. Milking machine equipment for use in parlours where the milk is collected in the can. The spring balance has a movable scale so that the balance can be brought to zero for each milking. Note the "vacuum lift" to raise the can off the floor.

milking rate, or a decrease in yield of strippings, will result in higher milk yields; and lower labour costs are to be expected with shorter milking times. It would, however, be dangerous to assume that faster milking will automatically be followed by a decline in mastitis; very little is known about the influence of methods of milking on the incidence of this disease, but the problem is an urgent one and is now receiving attention.

### *Vacuum*

A number of workers have demonstrated the effect of vacuum level on milking. Almost all have shown that milking rate increases with rise in the vacuum level at which the machine is operated, being greater with fast milking cows [3, 4, 18]. Unfortunately, the yields of strippings also increase with higher vacuum, probably owing to teat-cup crawl at an earlier stage in milking, so that the full benefit of the faster milking cannot be realized. In Figure 14 it will be seen that a rise in vacuum from 10 to 25 in. Hg gives a mean increase of about 75% in the maximum milking rate, though the decrease in total milking time is only about 30%.

With the machines at present in use it would appear that raising the vacuum from the usual 15 in. Hg to 18 in. Hg would increase milking rate, and, in consequence, that milking time could be considerably reduced. If modifications in the design of the liner could be made to reduce the yields of strippings at high vacuum, then vacuums of over 20 in. Hg might be used. The main question to be resolved is whether high vacuum has the serious effect on mastitis incidence that it is commonly supposed to have; published research findings encourage the belief that higher vacuums than are now being used may not adversely affect mastitis, but the results are not yet conclusive [16].

It is important to realize that the vacuum applied

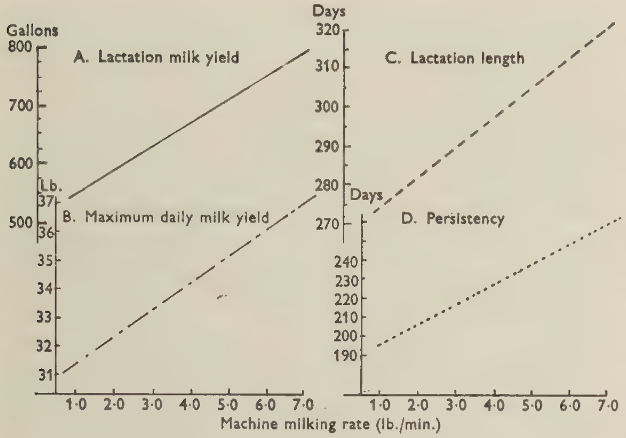


FIG. 13. The relationship between milking rate and lactation yield, lactation length, maximum daily yield and persistency of lactation, calculated from the records of 86 animals.

to the teats may be different from that indicated by the gauge in the main vacuum system. If milk is raised from the clawpiece to an overhead pipeline or interceptor jars, the vacuum level at the clawpiece will be less than that in the pipeline or jar by up to 5 in. Hg.

### *Pulsation*

The principle of pulsation was originally introduced to reduce the damaging effects of continuous vacuum on the tissues of the teat. In the double-action machine there are two phases in a pulsation cycle, and in both of them the inside of the liner is connected to the vacuum system. In one phase the pulsation chamber surrounding the liner is also connected to the vacuum system, and, with equal pressure inside and outside, the liner is in the normal or expanded position and milk will be withdrawn from the teat. In the other phase the pulsation chamber is opened to the atmosphere, and the rise in pressure in this chamber causes the liner to collapse round the teat and cut off milk flow (Figure 5). Thus milk flow becomes intermittent, and the best form of pulsation would be one that gives adequate relief to the teats with the least possible restriction of the milk flow.

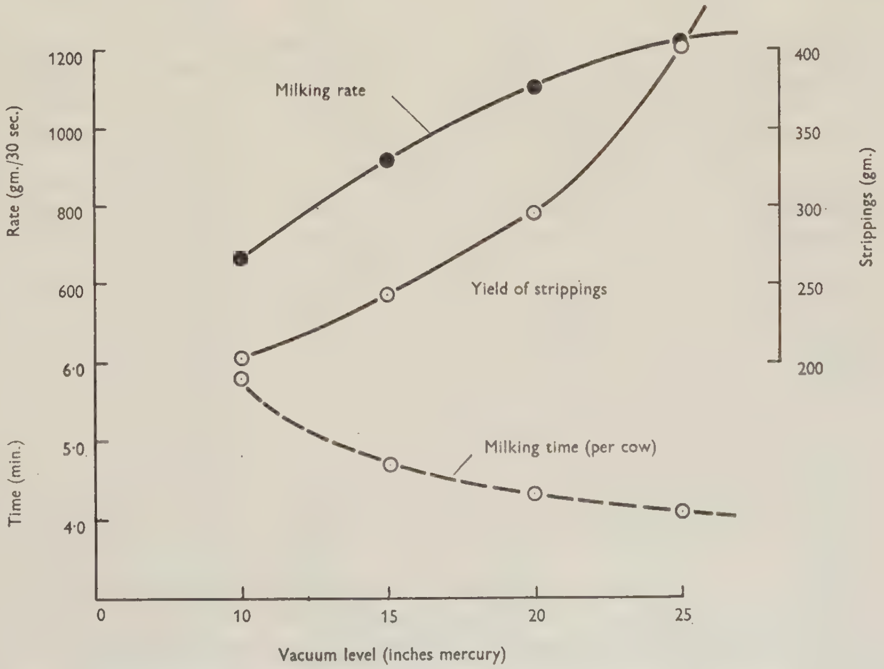


FIG. 14. The effect on milking rate, strippings and milking time of variation in vacuum.

The form in which pulsation is applied can be modified by changing the frequency of the pulsation cycles (i.e. pulsation rate) and by altering the ratio of the vacuum to atmospheric pressure phase of each cycle (i.e. pulsation ratio). Few attempts have been made to measure the effects of varying the pulsation rate on milking and milking rate and efficiency of stripping. Recently, however, it has been shown that, with a machine working with a pulsation ratio of 1 : 1, raising the pulsation rate from 50 to 80 cycles per min. will increase the maximum milking rate by 10%, whereas a decrease in pulsation rate of 20 cycles/min. will reduce it by almost 20% [7]. A reduction in milking time of over one minute per cow was achieved by increasing pulsation rate from 20 to 80 cycles per min.

Normally, in each pulsation cycle the liner is in the expanded milking position for the same length of time as it is in the closed position, and this is known as a 1 : 1 ratio. By increasing the length of the period of each cycle spent in the expanded position the ratio can be raised, e.g. to one of 2 : 1 or 3 : 1. Since milk flows when the liner is in the expanded position, it is to be expected that milking rate will be greater at wide pulsation ratios.

A preliminary study of the effect of pulsation ratios of 1 : 1, 2 : 1 and 3 : 1 has demonstrated increases in milking rate of up to about 10% with the wider ratios [18], and work in progress at the N.I.R.D. indicates that widening the ratio can increase the maximum milking rate by up to 45% [5]. At the present time this is the aspect most in need of thorough investigation, for the farmer can buy machines that operate at wide ratios and the effect of wide-ratio pulsation on milking rate and mastitis has not been measured. Moreover, variation in pulsation is the simplest way of substantially improving the performance of machines.

### *Teat-cup Liner Design*

The teat-cup liner is the component through which the vacuum and pulsation are applied to the teat, and it is the component showing the biggest variation in design. The liners vary greatly in dimensions, in design of the mouthpiece, and in the tension of the rubber in the main body of the liner. There is now evidence that these features can affect both rate of milking and efficiency of stripping. If milking machines are operating at similar vacuum, and have similar pulsation, differences between their performances are then due to teat-cup liner design. The effects are small but important, for even a 10% increase in milking rate or a 25% reduction in strippings could appreciably reduce the total milking time of a large herd.

Since the influence of the liner mouthpiece on strippings is not clearly understood, the effect of a change in design cannot be predicted. Yet trials have shown that, even with the same type of liner, a change in mouthpiece design can reduce the yield of strippings from an average of 2·0 lb./cow to under 1·0 lb./cow. The importance of this has been reinforced by "work-study" investigations of milking, which usually indicate that 20–30% of the milker's time during milking is spent in manipulation of the machines in removing strippings.

Design of the barrel of the liner affects the way in which the vacuum and the pulsation are applied to the teat, and so alters the rate of milk flow. In this respect the dimensions of the liner and the physical properties of the rubber with which it is made [8] are both likely to be important.

One of the main differences between types of teat-cup liner is in the extent of elongation of the barrel of the liner when fitted in the teat-cup shell. This may amount to an increase in length of 25%. Experimentally it is easier to measure the load needed to pull the liner into the milking position than elongation, and this tension ranges from 1 to 20 lb. In recent experiments [6] the effect on milking rate of varying this load from 5 to 45 lb. was ascertained with one design of liner: with increase in load from 5 to about 30 lb. there was a 20% rise in the maximum milking rate; thereafter the rate fell, probably because of the greatly decreased internal diameter of the liner at the high tensions.

Problems arise in the practical application of these findings owing to the difficulties of maintaining high tension in liners, especially with some forms of synthetic rubber and where the barrel of the liner is permanently attached to the stem. There is good evidence also that the rate of absorption of fat by the rubber liner from the milk and the skin of the teat is greater with high tension liners. This may be a serious problem with some forms of liner, because fat absorption is one of the main reasons for the short life of rubber liners. On the other hand, simple cleaning and maintenance routines can be followed using two-piece liners (i.e. liners having a separate barrel and milk stem) to maintain tension and milking performance and to reduce the level of absorbed fat in the rubber.

### *Weight of the Teat-cup Assembly*

Another factor known to influence machine performance, particularly in stripping, is the weight of the whole teat-cup assembly. For a given design of liner the amount of milk obtained as strippings decreases as the weight of the liner increases. The beneficial effect of weight in the clawpiece in reducing strippings has been commercially exploited in the "suspended machine," in which the amount of strippings is kept low because the downward pull of the teat cup becomes greater as the milk accumulates in the bucket. But the primary mechanical factor in determining the amount of strippings is design of the liner; weight is secondary.

In investigating these problems the "half-udder" technique has proved very useful. Using special milking machines (Figure 7) it is possible to apply different experimental treatments to the right and left halves of the udder, and to measure their effect on rate of milking. In this way a much better control and economy is obtained without reducing the value of the results. With such machines, and by carrying out experiments with identical twin cattle, it is not hard to determine the effects of the properties of the machine on its performance. The difficulty is usually to demonstrate the reasons for any changes produced, and there is little doubt that investigation into the way in which pulsation and liner design affect milking rate will represent the next step in the study of the action of the milking machine.

### INSTALLATION AND EQUIPMENT

All milking machines in use in Great Britain at the present time are of the double-action type and work on the principles outlined, but the ways in which manufacturers incorporate these principles into the equipment supplied for milking a herd of cows are diverse.

A milking machine installation consists of a permanent vacuum system to which units are attached for milking. The essential components of a unit are four teat cups fitted with rubber liners which are connected to a metal clawpiece. Milk from the liners is transferred from the clawpiece to a closed collecting vessel by means of a single rubber tube. (In the case of pipeline machines, a fixed milk pipe links the rubber tube from the clawpiece to the collecting vessel in an adjacent room.) A second rubber tube connects the lid of the collecting vessel to the vacuum system in such a way that milk is not drawn into the main vacuum system and vacuum pump. A pulsator mechanism is coupled by a rubber tube to the clawpiece which distributes the pulsation to the four teat cups.

#### *Types of Installation*

The permanent vacuum system comprises a fixed pipeline fitted with an automatic pressure-regulating valve and a vacuum-indicator gauge. This system is evacuated by a rotary or piston-type vacuum pump driven by an electric motor or a petrol or diesel engine.

To lessen noise in the cowshed or milking parlour it is usual to mount the pump and motor or engine in a neighbouring room. Many of the troubles encountered during milking are due to excess air leaking into the vacuum system, and detection of such faults is much easier in the absence of the noise associated with most vacuum pumps.

Milking machines are of two main types: mobile machines, designed for use in cowsheds where the milking unit is transferred from cow to cow; and fixed machines, installed in milking parlours and portable milking bails in which the cows move to the units to be milked.

The 1954 Agricultural Machinery Census indicates that about 93% of the milking machines in England and Wales are for cowshed use, and the great majority of these are bucket-unit models. Most dairy farmers have to milk in cowsheds, and the bucket-unit plant provides a sound means of milking under these conditions. The serious disadvantage of this system is the time and energy wasted in carrying buckets and small quantities of milk from place to place; but this may be partially overcome by using trolleys, moved along behind the cows, to carry the milk cans and recording equipment (Figure 8). An alternative method of reducing walking and carrying is to use one of the mobile milking machines. These are wheeled about in the cowshed or run on overhead tracks (Figure 11) and collect the milk in the cans in which it is delivered to the creamery without the need for tipping. The best types have the least equipment to move from cow to cow, and the fewest and simplest surfaces to come in contact with the milk.

In milking parlours and portable milking bails the can in which the milk is sent to the creamery may be connected to the vacuum system and used as the collecting vessel, or milk may be drawn from the clawpiece into a pipeline and then released into cans in an adjacent room

Individual yields may be recorded with direct-to-can milking if the can is suspended from a spring balance (Figure 12). The adoption of direct-to-can milking has made it possible to reduce the surfaces coming in contact with milk during milking, and a simple process of immersion cleaning has been developed at the N.I.R.D. [19] (Figure 9). On farms where parlour milking is practised and milk is despatched in cans, the combination of direct-to-can milking and immersion cleaning is probably the best for use in Great Britain.

Modifications in pipeline machines to provide for the recording of individual yields tend to increase the surfaces that contact the milk, and the added complexity of transfer valves and interceptor jars makes cleaning difficult and more expensive. If permanent equipment for the purpose is not required, a pipeline installation can be easy to clean, and a recirculation cleaning system has been developed in New Zealand [17] which may be adopted for similar installations in Britain. Pipeline milking is particularly suited for use in portable milking bails and for large herds where milk is drawn directly into bulk collection tanks.

In machine milking it is important to be able to determine when stripping should start. For this purpose a number of indicators have been designed for bucket and parlour milking equipment. At the present time none of the sight glasses provided on bucket units gives a definite enough indication of the point at which stripping should start. The prototype sight glass designed at the N.I.R.D. is effective, and so is the milk-flow indicator developed for pipeline milkers by Whittlestone [21] (Figure 10). When milking is direct to a can suspended on a spring balance (Figure 12), the movement of the balance finger should be used to indicate the point at which stripping should start.

### *Milk Cooling*

The Milk and Dairies Regulations (1949) require that milk should be cooled to 50° F or within 5° F of the temperature of the water supply used for cooling, as soon as possible after the end of milking. This is to restrict bacterial growth and thereby to improve the keeping quality of the milk [14]. The corrugated open-surface cooler, designed for use when hand milking was the common practice, is not suited to most machine milking systems.

In milking parlours and portable milking bails in which milk is collected in the transport can, either at the milking unit or in the adjacent milk room, cooling in the can is best. With bucket milking the milk may be tipped into the transport can in the cowshed and the full cans moved to the milk room for in-can cooling.

Devices for in-can cooling usually consist of a simple water turbine which is placed on the neck of the can, rotates an agitator in the milk, and then cascades the used water over the outside of the can. Good models will cool a 10-gal. can of milk in 10–15 min. to within 5° F of the water temperature, using 30–35 gal. of water. Types for use under vacuum to permit cooling during milking require more water per unit volume of milk cooled, but may save a little time because cooling is completed when a can is filled.

In-can cooling without the use of cooling equipment in the milk is possible where water supply is adequate. Immersion of the can in a trough or tank of running water, or the use of a "sparge ring" on the neck of the can to cascade water over the outside, permits cooling without agitation of the milk. Each requires about 60 gal. of water to cool 10 gal. of milk to within 5° F of the water temperature in 1–1½ hours. Although expensive in terms of water, these methods remove the danger of bacterial contamination of milk from the surfaces of cooling equipment.

Refrigerated cooling is the most efficient way of rapidly reducing the temperature of milk, but it costs about 0·75 pence per gallon of milk compared with about 0·05 pence per gallon where water cooling is used [14]. It is not economic in Britain unless the milk is stored in a bulk tank and collected in refrigerated tankers, or where the farmer is a producer-retailer, or where general cleanliness is bad and a really efficient cooling system is necessary to prevent milk from souring before reaching the creamery.

## USE OF THE MILKING MACHINE

Study of the intelligent use of the milking machine demands a knowledge not only of the properties of a milking machine, but of the anatomy of the udder and the physiology of lactation. It is now accepted that lactation has two parts—a continuous process of secretion, and ejection which occurs only at milking time. After milk is secreted it is stored in the alveoli and fine ducts of the udder, where it is held by capillary forces until milk ejection or "let-down" allows it to be squeezed from these tissues. Clearly ejection is of fundamental importance, for until it has occurred the milker can remove only a very small proportion of the secreted milk.

Milk ejection is a neuro-hormonal reflex in which the posterior pituitary gland, on receiving a nervous stimulus at the start of suckling or milking, secretes the hormone oxytocin into the blood stream. On reaching the udder the hormone causes the myoepithelial cells around the alveoli to contract, thus forcing the milk from the secretory tissues to the udder sinus and teats, from which it can be removed by the milker. This reflex is a transitory phase, and, if milking does not follow, the udder will return, after about 30 minutes, to a state similar to that before ejection occurred. There is also good evidence that the reflex is inhibited by the release of adrenalin. It is only in the last twenty-five years that the physiology of milk ejection has been correctly described, and the credit for realizing the practical implications of these discoveries must go to Professor W. E. Petersen of Minnesota.

The efforts of the newborn calf to suck from its mother are the natural unconditioned stimulus to milk ejection. Fortunately, European breeds of cattle can readily be conditioned to accept other stimuli associated with milking or the preparation for milking: feeding concentrates before milking, udder washing, the use of the foremilk cup, even noise, can all be developed into strong conditioned stimuli for milk ejection. For a conditioned stimulus to initiate a strong reflex, it must always be followed by the inborn stimulus (in this case, milking itself), and the interval between the two must be short and vary little. A very regular routine is therefore essential to good milking.

### *Preparation for Milking*

In practice the organization of a good milking system is not as complicated as at first sight it appears to be. Quite apart from any effects that the preparation for milking has on milk ejection, a smooth routine of work is essential. The milker has so many jobs to carry out just before milking that these have to be done in a constant order so that none is forgotten and time and mental effort are not wasted in thinking out the next steps. The only additional principle brought out by recent work on the physiology of lactation is that, because milk ejection is transitory and strong conditioned reflexes must be built up, operations in preparation for milking should be carried out separately for each cow at a *constant short* interval (under 3 minutes) before the animal is milked [11]. Milking should also be painless and without unusual noise, in order to avoid the risk of an increased secretion of adrenalin. A further point to be taken into account is that conditioned reflexes can be inhibited by interposing an unusual stimulus between the conditioned stimulus (e.g. udder washing) and the unconditioned stimulus (i.e. the start of milking). This explains why the presence of a stranger in the milking shed often decreases yields of milk and fat, and the effect is greatest in well-managed herds where strong conditioned reflexes have been built up.

It has been difficult to demonstrate experimentally the value of improved routines in terms of increased lactation yields; but a change in routine has been shown to have bad effects, particularly on fat percentage and milking rate. There is also evidence that yields of residual milk (i.e. milk remaining in the upper udder at the end of milking) are greater when preparation for milking takes place over 20 minutes before milking, compared with a constant interval of less than 3 minutes [11].

Feeding the grain ration immediately before milking can be built up into a strong conditioned stimulus to milk ejection. When carefully controlled it is a valuable aid to milking, but it has disadvantages. In cowshed milking, feeding is yet another job that involves carrying and walking, and it should therefore be done well before the start of milking. In a milking parlour, on the other hand, the use of feeding as an ejection stimulus can be very successful if control of food consumption is good. The main danger is that if the food is given to a cow on more than one occasion during milking the cow will become restless and may learn to kick off the milking machine unless more food is provided. Under these circumstances, feeding the grain ration during milking cannot be a strong ejection stimulus and will lead to waste of costly foodstuffs.

Because of the inconvenience of organizing routines where cows show wide differences in the duration of milking, a number of attempts have been made to "train" cows to milk quickly. In spite of the publicity given to the view that cows can be trained to milk in three or four minutes, results of extensive experiments have completely failed to confirm this [12]. In the light of the discovery that milking rate is mainly controlled by the anatomy of the teat sphincter, this is not really surprising. The only differences that can be made in milking rate are the result of changes in the efficiency of ejection. If a cow does not rapidly respond to the milk ejection stimuli, the machine may remain on the cow for one or two minutes before milk begins to flow. Similarly, it has been shown that the initial milk ejection may be partial, to be followed by a second ejection later in milking [22]. This phenomenon has been observed where a very irregular routine of milking is carried out, or where the milking machine is causing much pain.

### *Methods of Stripping*

Until recently there has been little agreement on methods of stripping the udder after machine milking. Because the milking machine cannot be modified in action and attachment to suit different shapes and sizes of teat at varying stages of lactation, it cannot withdraw all the milk. With the exception of first-lactation heifers, up to 10% of the available milk remains after the main flow period is completed, and this will be removed very slowly by the machine. At this stage it is usual either to take off the machine and handstrip or to manipulate the machine by pulling down on the clawpiece and then massage the udder so that the free flow of milk recommences. This process with the machine is known as machine stripping, and if properly carried out it dispenses with the need for hand stripping.

It has been suggested that it is not necessary to remove the strippings and that milk left after one milking will be removed at the next. Although this is substantially true, there is good evidence that incomplete milking in some way reduces milk yield, and if lactation is to be maintained it is necessary to take reasonable care in removing the strippings [2]. No milking, however, can be complete in the full sense of the word. In practice not more than 80–90% of the milk squeezed from the secretory tissues is ejected, the remainder being retained in the upper udder. This milk, usually termed residual milk, can be removed by giving an injection of oxytocin and milking again immediately afterwards [15]. Thus, incomplete milking has two forms: non-removal of the available milk, or incomplete stripping; and residual milk. Both are important, but it is probably of greater moment to ensure an efficient ejection and low residual milk—which may be up to 25% of the milk present at the start of milking—than to spend too long in removing the last few ounces of strippings.

To summarize, the principal finding is that milking methods and routines must conform to the individual differences between cows, not cows to the routine. Preparation for milking should be well ordered in such a way that it stimulates a strong milk ejection. The best routine seems to be one in which the cows are treated individually and each is prepared for milking within three minutes of the teat cup being attached to the udder. Variation in this interval is likely to have a considerable effect on milk yield and fat percentage. Machine stripping is probably the most suitable method of removing the last 5–10% of milk.

## CONCLUSION

In 1957 various types of milking machine are available from which a choice can be made to fit a particular size of herd and farming system. This article shows how the machine has evolved and should be used; but it deals essentially with research on machine performance and gives no guidance on many points of practical importance. The farmer still has to decide on the number of milking units to buy and the number of men to work them, how the machine should fit into the buildings if a milking parlour is required, and whether the parlour should be of an abreast or an in-line type and have one or two stalls for each milking machine unit. It is the answers to such questions that ultimately determine whether a milking machine will be used at its greatest economic efficiency. This farm management aspect of milking machines is a new and rapidly developing subject which, for reasons of space, has been excluded from this article. Another facet of management is the application of research findings. There can, for instance, be little reason in advising a farmer that he can reduce milking time by widening the pulsation ratio of his machines if his routine is such that the time that his machines are left on the cow is governed by the amount of work he does rather than the true milking time of his cows.

Thus, the tasks that face the research worker in machine milking at the present time are: to complete the investigation into the way that variation in the properties of the machine affects milking efficiency; to gain more knowledge on the way in which the machine should be used; and, probably the most important, to show how these results can be incorporated into a system of milking herds under widely differing circumstances with the greatest economic efficiency.

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# THE TOXIC ACTION OF HERBICIDES

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*So far most of the advances in selective weedkilling have been made by rule-of-thumb methods, and very little attention has been paid to fundamental aspects of the subject. We do not understand how these chemicals kill plants, and the biochemist now tends to believe that our best hope of making fresh discoveries is to learn very much more about normal life processes in the plant and the precise way in which toxicants affect them.*

Many of the most spectacular and certainly the most useful biological discoveries of this century have been concerned with the development of toxic chemicals for the elimination of pain, the control of disease or the destruction of pests. To the agriculturist, probably the most important have been the discoveries relating to the use of chemicals for the control of weeds.

Chemical weedkillers, or herbicides, are now the accepted tools of the husbandman, and their study has become a new branch of agricultural science. Progress in the subject has been rapid. Indeed, the number of different chemicals and formulations has increased at such a rate that many agriculturists find it difficult to keep informed of the changing situation. But there is, as yet, little scientific knowledge on which to base this new technology. Sixteen years have passed since it was shown that 2-methyl-4-chlorophenoxyacetic acid (MCPA) could be used as a selective weedkiller [27], and we are still far from understanding how this chemical acts in the plant. Our knowledge of the mode of action of the many other herbicides that have been discovered since then is little better. This paper can therefore do little more than collate some of the observations that have been made and demonstrate how inadequate they are as a basis for the proper understanding of herbicidal action.

The usefulness of herbicides depends not so much on general toxicity as on ability to destroy the weed without harming the crop; in other words, on their selective toxicity. Chemicals that lack this property have a restricted use. The science of selective toxicity must, however, be based on an understanding of the toxic action itself, and this requires a knowledge of the normal growth processes of the plant. Unfortunately our knowledge of these processes is extremely limited, and it now seems clear that in order to determine how plants die it will first be necessary to find out much more about how they live.

## PHASES OF ACTION

This paper is primarily concerned with toxic effects at cell level. Nevertheless, a study of herbicidal action must also take into consideration the many factors that determine the amount of chemical that eventually arrives at the site of action, as well as the ways in which the toxic act results in the death of the plant. Herbicides can kill plants in various ways. Death may occur in a few minutes, as when sulphuric acid is sprayed on young seedlings, or it may be long delayed, as when MCPA is applied to a resistant weed. In all cases, however, the action of the herbicide may be divided into three distinct phases:

*First*, the arrival of the chemical at the surface of the plant and its passage to the site of action.

*Second*, the specific toxic effects on metabolic processes of the plant at the site of action.

*Third*, the sequence of events that the toxic action sets in motion and which culminate in death.

Whether a herbicide is applied to the plant or the soil, the amount that reaches the plant surface is influenced by many variables. Retention by leaves is dependent on the physical and chemical properties of the spray liquid, the method of application, and the nature of the leaf surfaces. Movement of a herbicide to the absorbing surfaces of the roots is controlled by such factors as soil type, rainfall, and resistance of the chemical to decomposition by soil micro-organisms.

### *Mode of Entry*

To enter a plant the herbicide must pass through the cuticle, which covers all plant parts exposed to the air, even those lining the air spaces inside the leaf. The cuticle is not a simple, impervious, inert layer as was once supposed, but a complex living structure that controls the entry of both water-soluble and oil-soluble compounds. In higher plants the cuticle consists of a framework of cutin in which are embedded a series of interconnecting wax platelets and from the outer surface of which a forest of wax rodlets protrude. On the inner side, where the cutin merges into the cellulose of the epidermal cell walls, there is often a thin layer of pectin, while permeating this and connecting the whole cuticle with the living protoplasm are thin protoplasmic strands [29]. Because the cuticle is a living tissue, many of its properties, such as its permeability, are influenced by the conditions in which the plant is growing. For instance, dry, cold weather produces pea plants having a waxy cuticle that is more resistant to the penetration of herbicides than that of pea plants grown in humid, warm weather. In addition, it has recently been shown that the application of trichloroacetic acid to the soil before sowing pea crops can so change the nature of the leaf surfaces that the plants become susceptible to the normally safe herbicide dinoseb [9].

Uptake of chemicals by roots seems to be a less specific process than that by leaves. Most water-soluble herbicides enter roots, and it is thought that they are more readily absorbed than oil-soluble compounds; but little work has been done in this field, and our knowledge of the mode of entry of compounds that are not readily soluble in water is very limited.

### *Movement in Plants*

The first barriers to be met when the herbicide has passed through the cuticle of the leaf or the epidermis of the root are, respectively, the cells of the leaf mesophyll or the root cortex. Little is known about the cell-to-cell transport system that carries the herbicide along this chain of living cells and delivers it into the conducting tissues of either the phloem or the xylem. Nor is it known how closely the systems in the leaf and the root resemble each other. It has been ascertained, however, that the system in the leaf is a metabolic and not a physical process, and that it moves some chemicals faster than others. The rate of movement of 2,4-D between the leaf surface and the conducting tissue has been shown to be about 0·003 cm./hour [8].

Movement up and down the plant in the conducting tissues of the phloem and xylem enables the herbicide to be distributed throughout the plant. Upward movement in the xylem is generally associated with entry through the roots, and downward movement in the phloem with entry through the leaves. But most of the chemicals able to enter the phloem can pass from it into the xylem, and so are truly systemic in nature. Movement in the phloem depends on the flow of certain metabolites from the leaves, and its rate of 10–100 cm./hour is much faster than the cell-to-cell movement in the leaf. In practice, therefore, it is probable that the slower and more sensitive transport system of the leaf mesophyll determines whether or not a herbicide is capable of reaching the phloem.

### *Physiological Effects*

When the toxicant has reached its site of action and has blocked or inhibited the biochemical process or processes that it affects, abnormal growth results. The effects are complex, particularly if the toxicant is arriving at the site of action over an extended period and is not immediately lethal.

The information that is available on the manner in which different herbicides alter the growth and composition of treated plants tends to confuse rather than clarify an understanding of the mechanism of the toxic action, for the interval between time of application and analysis is so long that the direct effect of the toxicant has been masked by subsequent processes. The diversity of the after-effects of a herbicidal treatment is well illustrated by ways in which MCPA and 2,4-D can affect the growth of plants: they cause changes in respiration, carbohydrate utilization, nutrient uptake, mitosis, cell elongation, cell differentiation, and many other physiological processes. Death may be the direct result of any one of these upsets, or it may occur indirectly, as when the action of a toxicant paves the way for an attack by a pathogen.

## CLASSIFICATION OF HERBICIDES

In considering how the more important herbicides act, it is convenient to list the different types in accordance with some recognized system. A chemical classification is not very helpful, for the herbicides now in use have arisen mainly as the result of chance observations, and there is insufficient knowledge on which to relate chemical structure and activity, except within closely related types. Arrangement by biological effects would be confusing, because the changes that plants undergo in dying are extremely diverse and often far removed from the vital effects of herbicides. Lack of information rules out a list based on the mode of action. As a compromise, the arrangement adopted in Table I is based on the "transportability" within the plant, this being the property of a herbicide that limits its range of activity and determines how it can best be applied.

TABLE I

CLASSIFICATION OF HERBICIDES ON THE BASIS OF THEIR MOVEMENT IN PLANTS AND PLACE OF ENTRY

| Non-translocated | | Translocated | |
|---|---|---|---|
| Root entry | Foliar entry (Contact herbicides) | Upward (Xylem movement) | Upward and downward (Xylem, phloem and cell–cell movement) |
| | | Root entry | Foliar and root entry |
| Carbon disulphide | Sulphuric acid | Phenoxyethyl sulphates*<br>2,4-*DES* | Plant growth regulators |
| Methyl bromide | Copper salts | N-1-naphthylphthalamic acid | Phenoxyacetic acids<br>*MCPA*<br>2,4-*D*<br>2,4,5-*T* |
| Chloropicrin | Kainite ($MgSO_4$, KCl) | Phenyl carbamates†<br>*propham*<br>*CIPC* | Phenoxypropionic acids<br>2,4,5-*TP*<br>*MCPP* |
| Pentachlorophenol | Pentachlorophenol | | Phenoxybutyric acids<br>*MCPB* |
| Dinitrophenols<br>*DNC*<br>*dinoseb* | Dinitrophenols<br>*DNC*<br>*dinoseb* | Trichloroacetic acid | Sodium α,α-dichloropropionate (*dalapon*) |
| | Oils | Substituted ureas<br>*monuron* (*CMU*)<br>*diuron*<br>*fenuron* | Aminotriazole<br>Maleic hydrazide<br>Sodium chlorate |

* Active as 2,4-D. † Little information—some carbamates are moved freely.

In Table I "non-translocated" denotes herbicides that do not move within the plant and so exert their toxic effect only at the place of entry, in contrast to "translocated" materials which move freely in the conducting tissues and so can be toxic at a distance. Each of these groups is subdivided into chemicals that enter via the roots and via the foliage, though such a separation cannot always be clear cut. For instance, among the non-translocated herbicides are the dinitrophenols, which, although mainly used as foliar sprays, are also applied to the soil; and among the translocated herbicides most are able to enter plants through both shoots and roots. The fourth column of the table therefore includes herbicides that are applied to both the foliage and the soil, and which are capable of upward and downward movement in the plant. There are, as yet, no systemic herbicides that can enter only through the leaves.

This classification is too simple to deal accurately with all types of herbicides, and not enough is known about some (e.g. propham and CIPC) to place them definitely into any one category; but it does separate the chemicals well enough to serve as a background to the descriptions that follow. In this later discussion the herbicides are grouped according to their general mode of action and not necessarily in the order given in Table I.

## CONTACT HERBICIDES

Most of the earlier herbicides consist of strong acids, bases and salts and are used in large doses. Sulphuric acid is applied in concentrations of 5–70%, iron sulphate at 20–30%, and copper sulphate at 1–5%. The cellular reactions to such high concentrations are non-specific and bring about the denaturation and precipitation of protein in various ways [7].

### *Oils*

The two principal types of herbicidal oils are light distillates used for the selective control of weeds in umbelliferous crops and forest tree seedlings, and heavier distillates containing a high percentage of aromatic compounds, used for the non-selective control of weeds, particularly grasses.

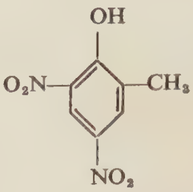
Oils wet plant surfaces readily, spread quickly over sprayed leaves and, if applied in large enough quantities, will flow between the leaves and reach the basal growing point of tall grasses. Oils of low viscosity enter leaves through the stomata and permeate the intercellular spaces for considerable distances.

Their primary toxic effect is due to a solvent action on the outer plasma membranes of the cells. The nature of this effect is not fully understood, but Van Overbeek and Blondeau [28] suggest that the hydrocarbon molecules displace the fatty molecules and thus destroy the semi-permeability of the membrane. Whatever the details, the end result is that the cell sap leaks into the intercellular spaces and the whole tissue dies. The resistance of carrots and other *Umbelliferae* to certain light oil fractions is believed to depend on some unique property of the outer plasma membrane [6].

### *Dinitro Alkyl Phenols*

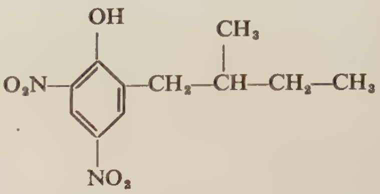
Dinitro phenols are toxic to a wide variety of plants and animals, including micro-organisms, and it has long been assumed that they interfere with some metabolic process common to all. It is now generally accepted that, in both animals and plants, the initial effect of low doses of DNC (I) or dinoseb (II) is to prevent the formation of energy-rich phosphate bonds, and that this "uncoupling" leads successively to increased respiration, reduced growth, and often death. DNC at low concentrations ($10^{-5}$M) has been shown to increase respiration in leaf discs of *Sinapis alba* [24]; but it is sprayed as a herbicide at a thousand times this strength, and, even allowing for its dilution after entering the leaf, many cells are likely to be exposed to concentrations much greater than are required for the stimulation of respiration. Additional mechanisms of toxic action then become apparent: respiration is inhibited, possibly by the action of flavoprotein enzymes; inhibition of fermentation follows; and proteins are denatured.

Dinoseb undoubtedly acts in much the same way. It probably owes its greater toxicity to most plant species and its selectivity in certain crops, such as peas and lucerne, to differences in retention and cuticular penetration.



(I)

3:5-*Dinitro-o-cresol*
(DNC)



(II)

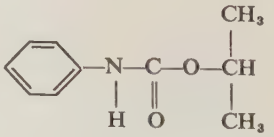
2:4-*Dinitro-6-sec-butylphenol*
(dinoseb)

## MITOTIC POISONS

### *Phenyl Carbamates*

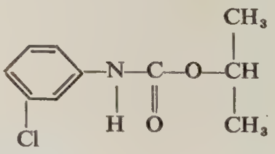
Of the many carbamates that have been tested as herbicides propham (III) and CIPC (IV) are still the most useful. They are applied as soil treatments at 4–8 lb./acre for the control of annual grasses and a few dicotyledonous weeds that grow during the winter in grass seed crops and lucerne.

The carbamates are mitotic poisons, i.e. owe their lethal effect to interference with the mechanism of cell division. Several workers [10, 15] have shown that the effects of propham on the dividing cell are similar to those caused by colchicine and often referred to as "C-mitosis." Spindle formation is inhibited, and the chromosomes fail to arrange themselves on the equatorial plane of the cell during metaphase. Cell elongation is also retarded. Treatment of whole plants increases the chlorophyll content by 19–28 % and affects respiration. At $10^{-4}$M propham almost completely inhibits the activity of certain respiratory enzymes, and Freed [11] suggests that this might be connected with blocking of cell division at the metaphase. It is, nevertheless, not clear whether the carbamates act directly on the dividing nucleus, or whether blockage at a particular stage of cell division is merely the result of a more fundamental action which may also influence cell elongation.



(III)

*Isopropyl N-phenyl carbamate*
(propham or IPC)



(IV)

*Isopropyl N-(3-chlorophenyl) carbamate*
(CIPC)

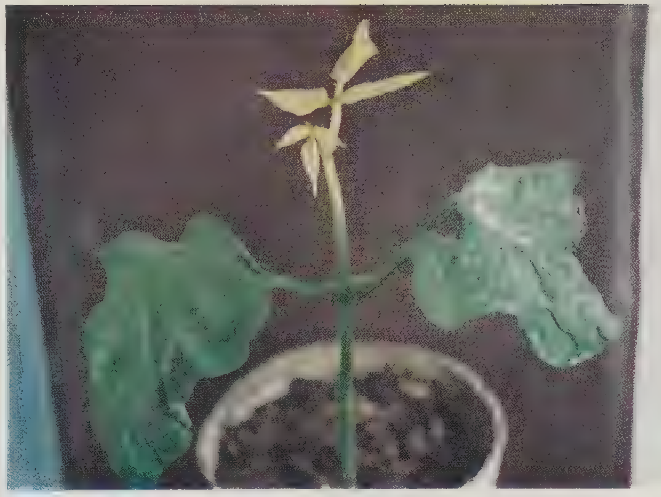


FIG. 1. Effect of aminotriazole on bean, showing chlorosis and chlorophyll breakdown

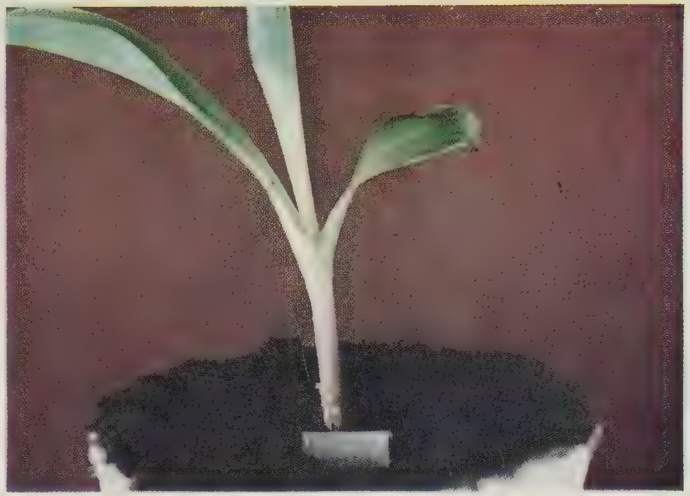


FIG. 2. Effect of aminotriazole on maize, showing chlorosis and anthocyanin pigmentation.

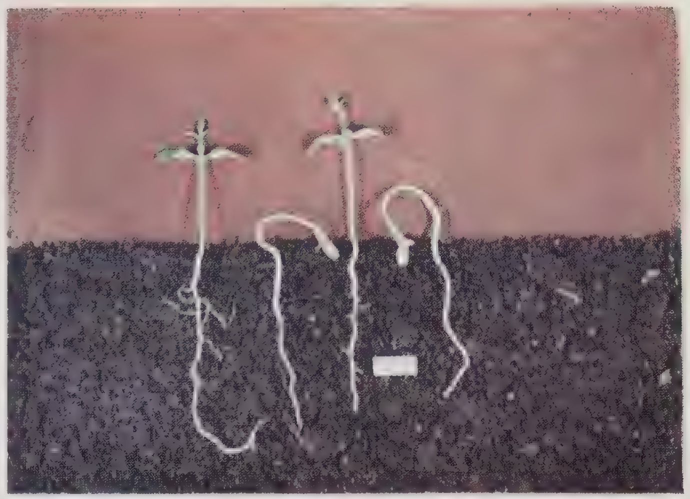


FIG. 3. Effect on linseed of a growth regulator that upsets geotropic and phototropic response.

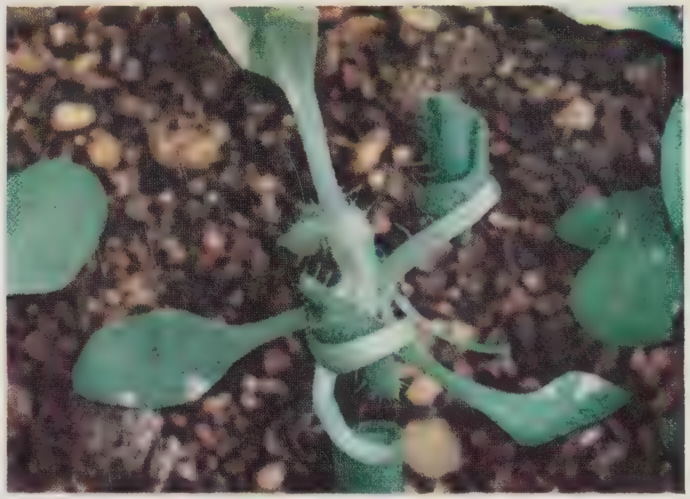
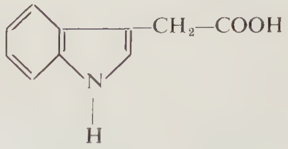


FIG. 4. Effect of MCPB on *Papaver rhoeas*, illustrating distortion.

### ''AUXIN-TYPE'' GROWTH REGULATORS

The many substituted phenoxy acids used as herbicides are shown in Table II. Their growth-regulating action is often very similar to that of the naturally occurring plant auxin, 3-indolylacetic acid (IAA), which is believed to control many aspects of growth in the normal plant. For instance, it affects meristematic cells, phototropic and geotropic responses, organ differentiation, root initiation, cambial activity, fruit development and abscission. Yet IAA is useless as a herbicide. The reason for this vital difference between the natural and the synthetic auxin is of fundamental

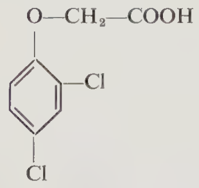
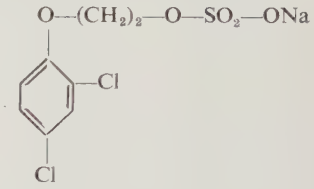
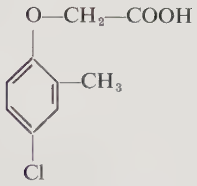
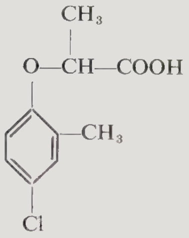
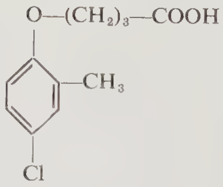
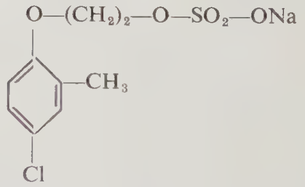
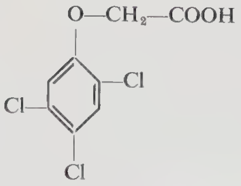
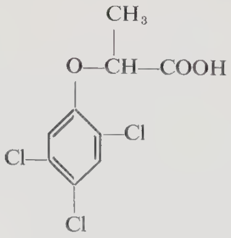
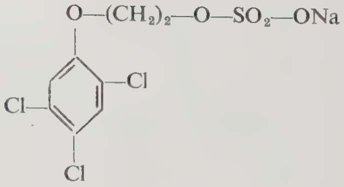


(V)

*3-Indolylacetic acid*
(IAA)

TABLE II

SUBSTITUTED PHENOXY COMPOUNDS USED AS HERBICIDES

| Acetic acids | α-Propionic acids | γ-Butyric acids | Sodium ethyl sulphates |
|---|---|---|---|
| <br>2:4-dichlorophenoxyacetic acid<br>(2,4-D) | | | <br>2:4-dichlorophenoxyethyl sulphate<br>(2,4-DES) |
| <br>2-methyl-4-chlorophenoxy-acetic acid<br>(MCPA) | <br>α-(2-methyl-4-chloro-phenoxy)-propionic acid<br>(MCPP) | <br>γ-(2-methyl-4-chloro-phenoxy)-*n*-butyric acid<br>(MCPB) | <br>2-methyl-4-chlorophenoxyethyl sulphate<br>(MCPES) |
| <br>2:4:5-trichlorophenoxy-acetic acid<br>(2,4,5-T) | <br>α-(2:4:5-trichlorophenoxy) propionic acid<br>(2,4,5-TP) | | <br>2:4:5-trichlorophenoxyethyl sulphate<br>(2,4,5-TES) |

importance. Several theories have been put forward, but none is completely convincing. It seems likely that a better understanding of the herbicidal action of these compounds will have to await explanation of the action of natural auxins.

The subsequent discussion is based on results obtained with 2,4-D, which has been tested much more extensively than any other herbicide. It is assumed, however, that structurally related herbicides will react in a similar manner.

### *Phenoxyacetic Acids*

Most of the herbicides now available are formulations of the substituted phenoxy acids listed in Table II. 2,4-D and MCPA are widely used, especially for the control of broad-leaved weeds in cereals. 2,4,5-T, which is the next in importance, is particularly useful for killing trees and shrubs. The effect of ring substitutions and changes in the alkyl side chain on growth-regulating activities has been ascertained using standard tests for measuring auxin activity, but little is known of the many other attributes which might qualify these compounds to become successful herbicides.

One major difference between 2,4-D and IAA is that 2,4-D when sprayed on plants causes abnormal growth whereas IAA does not. It has been established, first, that this effect of 2,4-D can be prevented completely by the simultaneous application of IAA and, second, that under certain conditions the treatment of plants with 2,4-D reduces their IAA content. These facts have led Weintraub [30] to postulate that the "vital" action of 2,4-D is its effect on natural auxin in the plant. Organized growth in leaves and stems depends on the polarized division of meristematic cells, and this is controlled by IAA. If, therefore, structurally related compounds, such as 2,4-D, competed with the natural auxin and brought about its deficiency, this might result in disorganized cell division, malformed leaves and stems, widespread derangement of metabolic and physical processes, and death. This theory depends on the accuracy of the general assumption, which is not generally accepted [3], that 2,4-D influences IAA levels within the plant and that such deficiencies result in unorganized cell division.

There are other theories which depend on a comparison of the effects of the natural and the synthetic auxin. One, not based on experimental evidence, suggests that the main difference between IAA and 2,4-D might be due to the presence in plants of an enzyme that inactivates IAA when this auxin is present in excess, but leaves 2,4-D unaffected and therefore free to exert its toxic effects. An IAA oxidase does exist in brei prepared from roots and etiolated aerial portions of some plants [12], but its presence in intact living plants has not been proved, nor do its characteristics fit in with the above suggestion.

Osborne [20] has put forward the theory, based on experiments with etiolated pea epicotyls, that the growth-promoting processes brought about by IAA are always associated with the production of an inhibitor which can protect the plant from its own auxin and that such safety mechanisms do not exist for synthetic compounds, and that is why 2,4-D and related chemicals act as herbicides. This theory is supported by the work of Ball and Dyke [4], who show that if whole plants are treated for short periods with IAA there is an initial stimulation of growth and then a fall to a growth rate below that of the control. Similar treatment with 2,4-D results in stimulation but no subsequent growth inhibition.

### *Phenoxypropionic Acids*

The α-phenoxypropionic acids (MCPP and 2,4,5-TP) have a different selective action from the corresponding acetic derivatives, e.g. MCPP is much more toxic to *Galium aparine* (cleavers) than MCPA, but less toxic to cereals. This makes it possible and convenient for the farmer to use a chemical that is harmless to mammals for the selective control of certain weeds against which he was once forced to use the dangerous sulphuric acid, DNC or dinoseb [17].

It is probable that the changes in relative toxicity which arise from these minor modifications to the aliphatic side chain are due primarily to the alteration in the physical properties of the molecule, and that this has a differential effect on retention, penetration and perhaps transport of the molecule in different species.

### *Phenoxybutyric Acids*

The mechanism of action of the γ-phenoxybutyric acids is better understood [32]. They are converted by β-oxidation systems within the plant to the active acetic homologues. Differences in the ability of crop and weed species to effect this conversion enable the compounds to be used in situations where the corresponding acetic acid homologue would be too toxic to the crop. Extending the side chain by two methylene groups also influences penetration and selectivity.

In British agriculture, MCPB is particularly useful because it is less toxic than MCPA to clovers, cereals and peas, yet almost as toxic to certain weeds of these crops, and so can be effective in situations where it is impracticable to use MCPA. Figure 4 illustrates its distorting effect on seedlings of *Papaver rhoeas* (corn poppy).

### *Sodium Ethyl Sulphates*

The sodium ethyl sulphate derivatives, like the phenoxybutyric acids, are more selective than their parent acetic acids because they are inactive until they have been converted to the phenoxyacetic acid. The conversion in this case is not accomplished by the plant but by soil micro-organisms, and selectivity is enhanced owing to the fact that the herbicide can no longer penetrate the leaves and enters only through roots.

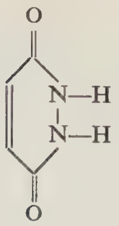
## OTHER GROWTH REGULATORS

### *Inhibitors of General Growth*

Maleic hydrazide (VI) differs from the growth regulators described above in that it retards overall plant growth without causing malformations. It is rapidly translocated from leaves and roots, and it has been used as a "herbistat" rather than as a herbicide, mainly to suppress the growth of grass. Its inhibitory effects are associated with a suppression of apical dominance, and suggestions have been made that it interferes with IAA activity. Tests have confirmed that it is a competitive inhibitor of IAA and 2,4-D and that it promotes the destruction of IAA by enzymes [16].

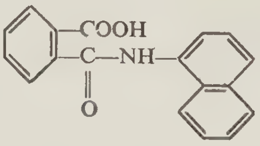
### *Inhibitors of Tropic Responses*

Templeman [26] has discussed the possible use as herbicides of compounds that affect the geotropic and phototropic responses of plants, and he has drawn attention to 2:4:6-tribromophenylnitramine and 2-chloro-9-fluorenol-9-carboxylic acid. Tri-iodobenzoic acid also influences geotropism, probably owing to its ability to control the activity and polarity of movement of IAA. N-1-naphthylphthalamic acid (VII) is the only herbicide in commercial use which influences geotropic and phototropic responses (Figure 3). Its herbicidal action is, however, often not directly due to this effect.



(VI)

*Maleic hydrazide*



(VII)

*N-1-Naphthylphthalamic acid*

## OTHER TRANSLOCATED HERBICIDES

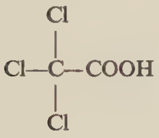
### *Sodium Chlorate*

Sodium chlorate has been used as a herbicide for fifty years. It is toxic to all higher plants, but several types of bacteria and fungi grow freely even in its concentrated solution. It is taken up by roots and leaves and seems to be readily translocated. Its toxic effects are slow to develop, often localized to particular organs, and sometimes conditioned by light and nitrate supply. These facts led earlier workers to suggest that it was not the chlorate ion which was toxic but some reaction product. More recent work has established fairly definitely that poisoning is the result of the reduction of the chlorate to hypochlorite and chlorite. In 1947 Åberg [1] suggested that the chlorate is reduced by the mechanisms which normally reduce nitrate in the plant. Since that time a great deal has been found out concerning the nitrate-reducing enzymes of plants, and Åberg's theory, which was based on circumstantial evidence, needs re-examining. It is now known, for instance, that molybdenum is present in the enzyme responsible for converting nitrate to nitrite, and that plants suffering from molybdenum deficiency accumulate nitrate because of a decrease in nitrate reductase activity [2]. It would be interesting, therefore, to know whether a deficiency of molybdenum influences the toxic action of chlorate.

### *Trichloroacetic Acid and Dalapon*

These two herbicides probably affect the same metabolic processes. They are used mainly for the control of grasses. The chief difference between them is that trichloroacetic acid (VIII) has to be applied to the soil and is not readily moved within the plant, whereas α,α-dichloropropionic acid or dalapon (IX) is freely transported in the phloem and xylem and can be applied either to soil or foliage. Both cause growth abnormalities similar to those produced by 2,4-D, but much less severe. Trichloroacetic acid is known to interact with 2,4-D in its effect on extension growth of root and shoot segments of peas [23]. It seems possible therefore that the herbicides interfere with the natural auxins of plants. Trichloroacetic acid is absorbed by both susceptible and resistant species but accumulates more in the latter, indicating that the metabolic breakdown of the herbicide and its toxic effect may be related.

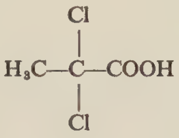
Another theory [21] is that dalapon might act as an antimetabolite to pyruvic acid, and tests have shown that enzyme systems involving pyruvic as a substrate (pyruvate oxidase and carboxylase) are inhibited by dalapon. Inhibition was, however, not great enough to be the primary cause of the herbicidal activity of dalapon.



$Cl{-}\overset{Cl}{\underset{Cl}{C}}{-}COOH$

(VIII)

*Trichloroacetic acid*



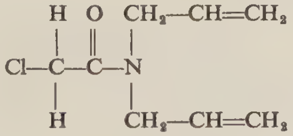
$H_3C{-}\overset{Cl}{\underset{Cl}{C}}{-}COOH$

(IX)

α-α-*Dichloropropionic acid* (dalapon)

### Chloroacetamides

1-chloro-N-N-diallylacetamide (X) is one of the most promising of a range of N-substituted α-chloroacetamides which have been tested [13]. These compounds have to be applied to the soil, and all are more toxic to grasses than to other weeds. Some cause minor formative effects. N-disubstituted derivatives with a straight chain aliphatic group are generally more active than N-monosubstituted compounds, and a three-carbon chain fulfils most of the requirements for maximum activity, although some heterocyclic derivatives are very active.



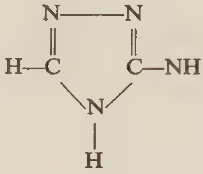
$Cl{-}\overset{H}{\underset{H}{C}}{-}\overset{O}{\overset{\|}{C}}{-}\underset{CH_2{-}CH{=}CH_2}{\overset{CH_2{-}CH{=}CH_2}{N}}$

(X)

1-*Chloro-N-N-diallylacetamide*

### Inhibitors of Chlorophyll Formation

Several compounds suppress chlorophyll development and cause chlorosis in plants. They include sulphanilamide and streptomycin, some tetronic acid derivatives, certain substituted benzoic acids, carbamates and O-methylthreonine. But the only useful herbicide having this property is aminotriazole (XI). This chemical, which is readily soluble in water, is promising for the control of annual grasses and deep-rooted perennials, and as a defoliant for cotton. It is readily absorbed by the roots and leaves of many plants. Tissues that are developing at the time of treatment became chlorotic to a degree depending on the dose applied (Figures 1 and 2). If sub-lethal doses are used, the chlorotic tissue may remain alive and regain its colour. Preliminary experiments have indicated that inhibition of chlorophyll synthesis is not due to the immobilization of magnesium or iron, and that it occurs before protochlorophyll is produced. Rogers [22] has observed that leaf sections, cut from maize plants made chlorotic by treatment with aminotriazole, contain no plastids, presumably because the chemical prevents their formation. It is not known whether the action of aminotriazole on chlorophyll is in any way connected with its effect on growth and abscission, but the discovery that it has a specific action on catalase [14] suggests that it may be acting on a more basic aspect of growth.

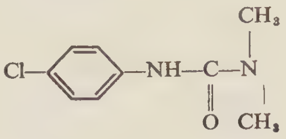


(XI)

*Aminotriazole*

### Inhibitors of Photosynthesis

Monuron (XII) is the best known of the three commercially available phenyl-substituted ureas. The other two, diuron and fenuron, contain respectively two and no chlorine substitutions in the benzene ring. All are highly toxic and persistent in the soil. They are absorbed by roots, from whence they move rapidly to the leaves. Seedlings treated with these compounds do not die until they have developed cotyledons and leaves, and chlorosis is the chief symptom of toxicity. More recent work [18] shows that monuron is relatively non-toxic to roots, and that excised roots can be grown for many months in a nutrient culture containing enough monuron to kill the whole plant. Several other workers have also shown that these compounds have a specific effect on the leaf; but not until Wessel and Van der Veen [31] demonstrated that monuron and other substituted ureas are extremely effective inhibitors of the photochemical activity of isolated chloroplasts were we given an indication of the real mechanism of action of these chemicals. Subsequently it has been confirmed [5, 25] that monuron inhibits the Hill reaction of photosynthesis at concentrations as low as $10^{-7}$M. This seems to pinpoint, for the first time, a precise chemical step in the phytotoxic action of a group of chemicals.



(XII)

*1-p-Chlorophenyl-3:3-dimethylurea*
(monuron or CMU)

## CHEMICAL STRUCTURE AND PHYTOTOXICITY

Study of the relationship between chemical structure and biological activity helped in other fields to interpret the mechanism of action of toxic chemicals. For instance, some compounds are known to be effective because they block the utilization of a metabolite that is essential to the growth of an organism. Their toxicity depends, therefore, on the similarity of their structure to that of the metabolite. No herbicide has been shown to act in this way, although some may do: the similarity between dalapon and pyruvic acid has already been pointed out.

As far as plants are concerned, the relationship between structure and effect has been most thoroughly investigated in growth regulators of the auxin type. Here it is possible to define in general terms the molecular configuration required for activity; but not all growth-regulating compounds are useful herbicides, and practically nothing is known of the molecular requirements for phytotoxic action. Several other groups of compounds, such as the phenylcarbamates and the N-substituted α-chloroacetamides, have been studied, but results have not been enlightening.

In short, despite the great advances made in the production and use of selective herbicides, we still know next to nothing about the ways in which they kill plants. This is not surprising. It may take the plant physiologist and the biochemist years of painstaking work to explain even a single step in any one of the chains of processes on which each function of the living plant is based—and this knowledge must be forthcoming before we can determine precisely how each particular toxicant upsets a normal function and so causes death.

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# DETAILED SOIL MAPS FOR EXPERIMENTAL FARMS

### A. J. Low

*Soils vary so much in type, even within a single field, that it is often difficult on agricultural research stations to select suitable sites for field trials. One answer to this problem is to make a detailed soil map of the experimental area, using factors of agronomic importance based on the soil profile in deciding categories for mapping.*

On farms attached to agricultural research stations, field experiments are now designed according to methods originally put forward by R. A. Fisher in which allowances are made for soil variation. If this soil variation has any effect on the factors being measured, the greater the variation over an experimental site, the higher will be the standard error. In selecting sites for field experiments, therefore, everything is to be gained by having an area as uniform as possible in soil characteristics, and very detailed soil maps of the areas concerned are essential.

The basis of all soil classification is the profile. On large-scale maps, e.g. 1 : 2,500 (25 in. = 1 mile), the taxonomic unit is normally the soil type or phase and it is the boundaries of the different types which are marked. The soil type is a subdivision of the soil series* and differs from it only in the texture of the surface soil.

Anyone familiar with soil profiles in the field is aware of the difficulties in making decisions as to whether two or more belong to the same type or series. This is clearly recognized by the United States Department of Agriculture [1], viz. "If every single observable characteristic in two soil profiles had to be identical to permit placing the two in the same soil series every profile examined would be a separate series, for no two profiles are like in all respects." Clearly some variation in depth of the individual soil horizons must be expected; some variation in soil property must be allowed. This means that placing a range of soil profiles in a series or type is, in the end, dependent on the personal opinion of the soil surveyor—a not entirely satisfactory state of affairs.

The soils of the United Kingdom are relatively young and their characteristics tend to be dominated by their parent material. Much of the country north of a line drawn from London to Bristol is covered with glacial drift; and to the south of this line, where there was no ice sheet during the Glacial epoch, solifluxion had a profound effect on the arrangement of the superficial deposits. In addition, the mineral composition of the rocks is so varied that the possible number of soil series and types is very large. Thus, when an attempt is made by examination of profiles to map a small area (e.g. $\frac{1}{4}$ acre) in great detail on a soil type basis, the judgment of the soil surveyor may be greatly taxed.

Some years ago we tried to produce a detailed soil map of the farm at Jealott's Hill Research Station, Berkshire, based on the soil type as already defined. The farm lies on an outcrop of the London Clay, having a clay content ($<2\ \mu$) of at least 65%, and this is covered on the higher parts by sand and gravel deposits known as Plateau Gravel. As a result of solifluxion these deposits have spread in a random manner over the London Clay, which, though homogeneous through most of its mass, is interbedded with layers of sand at its base and top. The Plateau Gravel consists of sub-angular flints and Tertiary flint pebbles and cherts mixed with sand. In addition, there is evidence for windborne deposits over much, if not all, of the farm. Considerable variation was found in soil profiles a few yards apart, and it was decided that for this particular area a map based on the soil type would be far too complex to be of value as a guide in the siting of field experiments.

On experimental farms the purpose of the soil map is to aid the work of the agronomist, who is concerned with soil variations of importance to the growth of crop plants. In an attempt to overcome some of the difficulties referred to, a soil

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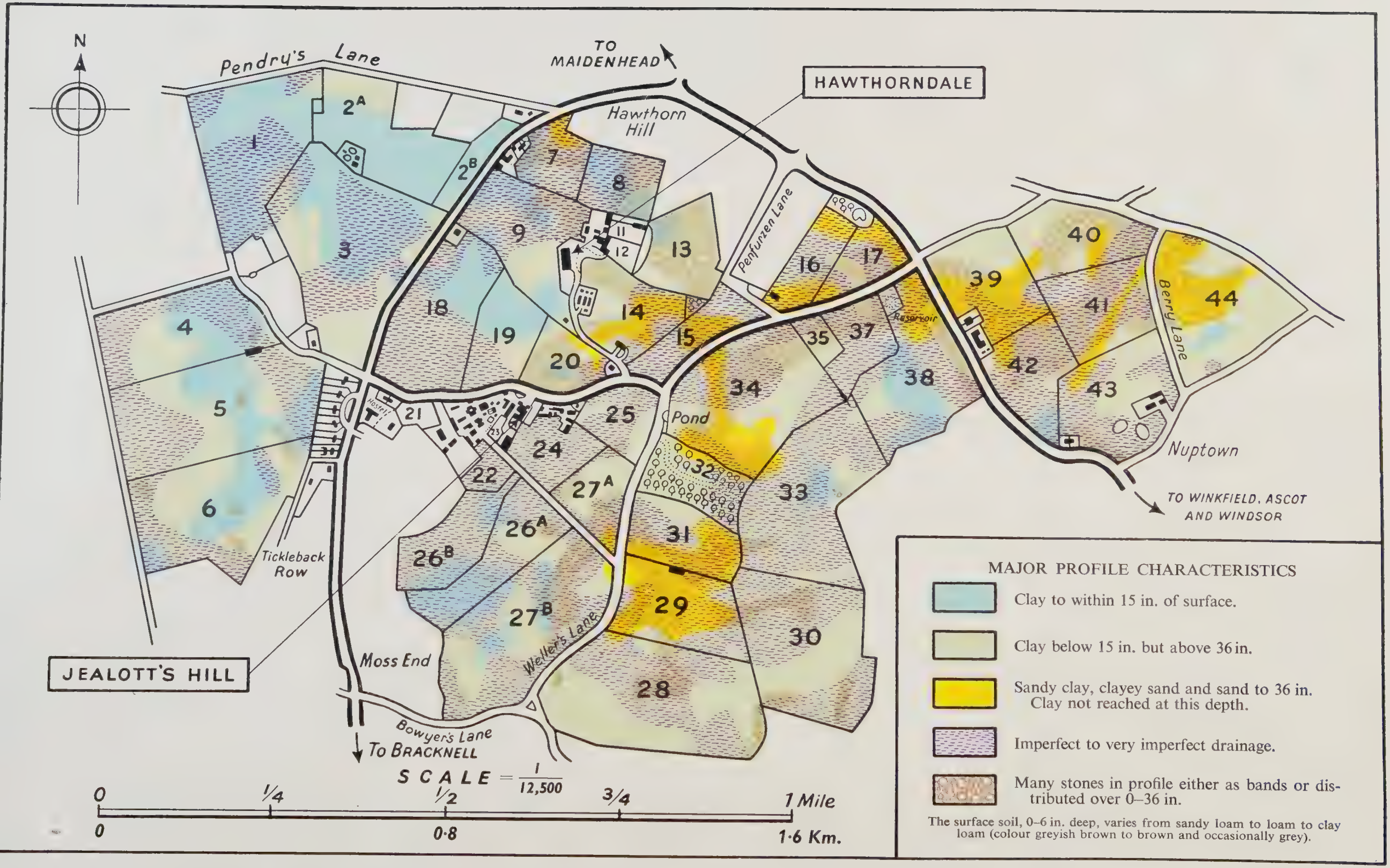
* The United States Department of Agriculture [1] defines the series as follows: "The soil series is a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile except for the texture of the surface soil and developed from a particular type of parent material. The soils within a series are essentially homogeneous in all soil profile characteristics except texture, principally of the A or surface horizon and in such features as slope, stoniness, degree of erosion, topographic position and depth to bedrock where these features do not modify greatly the kind and arrangement of soil horizons. . . . The soil type is a subdivision of the soil series based on the texture of the surface soil."


N
Pendry's Lane
TO MAIDENHEAD
HAWTHORNDALE
Hawthorn Hill
Penfurzen Lane
Berry Lane
Reservoir
Pond
Nuptown
TO WINKFIELD, ASCOT AND WINDSOR
Tickleback Row
Hostel
Moss End
Weller's Lane
Bowyer's Lane
To BRACKNELL
JEALOTT'S HILL
1
2A
2B
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43
44
SCALE = 1/12,500
0
1/4
1/2
3/4
1 Mile
0
0·8
1·6 Km.
MAJOR PROFILE CHARACTERISTICS
Clay to within 15 in. of surface.
Clay below 15 in. but above 36 in.
Sandy clay, clayey sand and sand to 36 in. Clay not reached at this depth.
Imperfect to very imperfect drainage.
Many stones in profile either as bands or distributed over 0–36 in.
The surface soil, 0–6 in. deep, varies from sandy loam to loam to clay loam (colour greyish brown to brown and occasionally grey).

FIG. 1. A simplified soil map of Jealott's Hill farm prepared for general use by superimposing maps of the main profile characteristics.

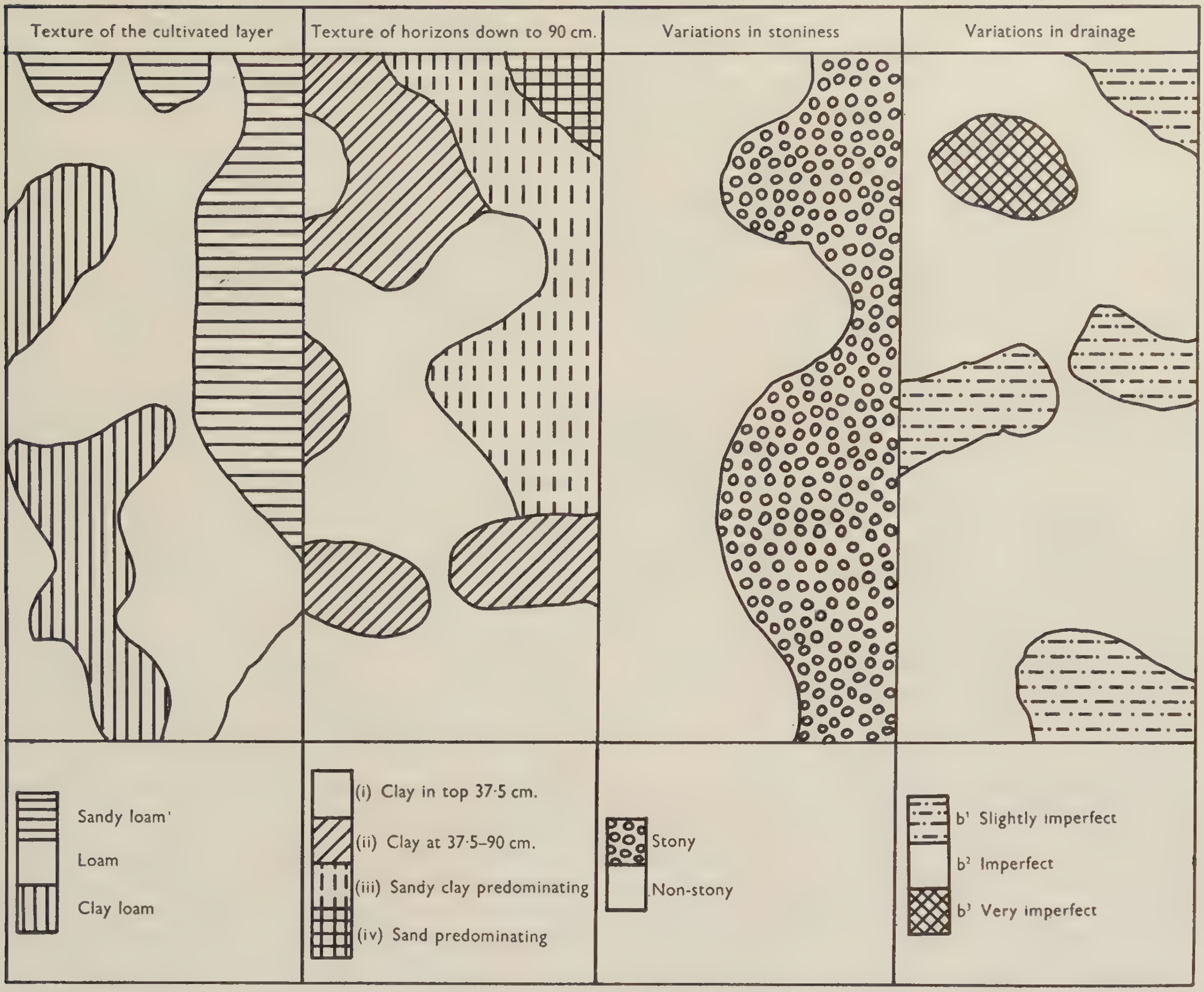

FIG. 2. Separate maps of the four main profile characteristics in a small section of a field. By superimposing these as transparencies a clear idea of the nature of the soil is obtained.

map of Jealott's Hill was produced, based on profile characteristics of agronomic importance rather than on the type or series. A network of points chosen to give a uniform cover was first marked on a map of the area to be surveyed. At each, auger observations to 90 cm. were made, and a detailed description at each point was recorded in the usual manner. Pits were dug and chemical and physical determinations made to get more detailed information of the commoner profiles observed. The final number of auger borings and pits depended on the extent of profile variation. In the example given in Figure 2 about 5–15 examinations per acre were made.

The profile characteristics were then classified into four groups:

1. Texture of the cultivated layer (usually upper 15–20 cm.).
2. Texture of horizons down to 90 cm.
3. Variations in stoniness.
4. Variations in drainage.

Each of these was subdivided from agronomic considerations as follows:

1. *Texture of the Cultivated Layer.* This is very important in determining the type of structure that will develop in different rotations. Soil textures at Jealott's Hill ranged from sandy loam to clay loam, but only three were used in making the map, viz.:
    (i) Sandy loam.
    (ii) Loam.
    (iii) Clay loam.
2. *Texture of the Horizons down to* 90 *cm.* This is equal in agricultural importance to the surface texture; it largely determines the natural structure below the cultivated layer, which in turn

affects drainage characteristics, ease of penetration of roots, water-holding capacity, aeration, etc. With these characteristics in mind, the profiles were divided into five groups, depending on:

- (i) Clay occurring within 37·5 cm. of the surface and persisting to 90 cm.
- (ii) No clay within 37·5 cm. of the surface but occurring and persisting between 37·5 and 90 cm., i.e. below the main zone of development of most root crops.
- (iii) Sandy clay predominating but tending to be rather variable, with occasional thin horizons of clay.
- (iv) Sand predominating, but with enough clay to bind it when moulded between the fingers.
- (v) Sand with little or no clay at any depth.

3. *Variations in Stoniness.* A few stones scattered through the profile have little agricultural significance. Stony horizons, however, within 45 cm. of the surface can cause difficulties in cultivation and root development of such crops as sugar beet. Consequently the soils were divided into two groups according to the amount of stones and gravel (all material greater than 2 mm.) they contained:
   - (i) *Stony*, if stones were present in high concentrations within 45 cm. of the surface, i.e. sufficient to make penetration with an auger difficult or impossible.
   - (ii) *Non-stony*, if stones were not present in high concentrations within 45 cm. of the surface.

   In practice, the high concentrations were usually between 20 and 30 cm. from the surface. Where mechanical analyses were carried out, soils with 20% or more by weight of gravel and stones in the upper 45 cm. were classified as stony.
4. *Variations in Drainage.* The drainage at Jealott's Hill is mostly imperfect, and the following subdivisions were used:
   - *a*. *Free*—no indications of drainage impedance.
   - $b^1$. *Slightly imperfect*—no indications of drainage impedance to 37·5 cm., then occasional rusty mottlings and $MnO_2$ concretions.
   - $b^2$. *Imperfect*—some rusty mottling at 15–37·5 cm.; orange mottling below 37·5 cm., with a greenish-blue to greyish-blue gleyed horizon under this.
   - $b^3$. *Very imperfect*—roots coated with iron rust and rusty iron oxide concretions in the top 15 cm.; and lower (within 37·5 cm. of the surface) orange mottling followed by a greenish-blue to greyish-blue gleyed horizon.

   Soils in sub-division *a* tend, at Jealott's Hill, to have a poor capacity for storing available water. The degree of drainage impedance in $b^1$ is such that farm crops are not likely to be damaged by excess of water at any time. In $b^2$ waterlogging is liable to occur for very short periods and plants may be damaged. In $b^3$ waterlogged conditions tend to persist for some weeks during the wetter periods of the year and plant growth suffers badly.

By using this somewhat arbitrary classification little is left to the judgment of the worker. Arithmetically, 120 different profile combinations are possible, but in practice some would not occur. If many different combinations of this kind are found frequently in a *small* area where mapping based on the soil type is being attempted, it is clear that unless some of these combinations are grouped together and regarded as one type (so ignoring the precise definition of this term) the map would be so complex that it would be not only difficult to prepare but of little practical value. Moreover, with such a grouping much information of agronomic importance cannot be presented.

In order to overcome this difficulty, separate maps based on the four main classifications were drawn. An example taken from a field at Jealott's Hill is given in Figure 2. This area is on a gentle slope down which solifluxion has taken place. Maps such as this have been of value in siting field experiments and also in accounting for numerous observations of crop variations.

Where the constituent maps are not too complicated, a composite map can be produced. With its aid the probable profile characteristics at any point can be read off. Figure 1 is a simplified map of this type at Jealott's Hill farm, used for visitors examining field experiments.

Both types of map have been in use at Jealott's Hill for the past six years and have been found satisfactory. It is thought that there may be other areas in the world where a similar method of approach merits consideration.

ACKNOWLEDGMENT

This paper was read at the 6th International Congress of Soil Science, Paris 1956, and is reproduced here by permission of the Secretary of the International Society of Soil Science.

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# METHODS OF INSECTICIDE APPLICATION AGAINST THE DESERT LOCUST

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*This paper was read at the Plant Protection Second International Conference, Fernhurst, 1956. It shows that insecticides may give poor or excellent kills of the desert locust, whether applied in baits for hopper control or sprayed from aircraft against adults in settled or flying swarms. Much depends on locust density and other factors affecting pick-up, and these must be taken into account if efficiency in control is to be improved.*

Operations against the desert locust (*Schistocera gregaria*) are at present costing the sixty-four territories concerned, from Morocco to India and from Iran to Tanganyika, more than £5 million a year. While control measures on this scale appear so far to have averted serious crop loss in most countries, there is evidence [7] that locust numbers are from time to time large in relation to the maximum effort so far brought to bear on them; and in Morocco alone two years ago, crop damage officially assessed at £4½ million was inflicted in a single season. The magnitude of the threat, and the financial burden of current control measures, make it essential to use every opportunity of increasing the efficiency of control operations.

The most widely used of established methods is poison baiting, using a stomach insecticide such as γ-BHC or aldrin at about 0·1 % in a carrier such as wheat bran, crushed millet or rice husks, and now normally applied dry [1]. Under favourable conditions the efficiency of the insecticide in baiting may be very high; a figure of 34 kg. of third-instar hoppers/g. γ-BHC was recorded in a small-scale field trial in Kenya two years ago, which may be compared with the figure of 2·2 kg. of adult locusts/g. γ-BHC given by the best aircraft-spraying kill so far recorded against swarms. In recent bait assessments by C. Ashall in Ethiopia (not yet published), kills of more than 15 kg. hoppers/g. γ-BHC have been recorded against the 1st, 3rd, 4th and 5th instars. The method is moreover well suited to unskilled local labour in remote areas, but has two serious shortcomings. The first is that the cost of application per unit of active ingredient is extremely high—about twenty times the corresponding aircraft spraying costs per unit of active ingredient, in comparable ground and air campaigns in eastern Africa in 1953–4—owing to the cost of the carrier and its transport, which may together account for more than half the overall costs of a typical campaign. The second shortcoming of baiting is a measure of unreliability of action, particularly against the older hoppers, of which both the extent in practice and the mechanism are as yet unknown. It is illustrated by the fact that three of the ten field assessments of bait kills of 5th instar hoppers so far recorded have been at rates of less than 0·1 kg. of hoppers/g. γ-BHC, although in each case the whole of the bait applied was eaten by the hoppers.

Dusting is still used mainly against the earlier instars and in territories where satisfactory bait carriers are not available. Very occasionally, dusting both with DNC and BHC has given excellent kills on adult swarms, particularly when the locusts were wet with rain or dew. Against adults under more typical, drier conditions, negligible kills have been recorded on a number of occasions with both materials.

Spraying by ground machinery is not at present a major control method against the desert locust. The mobility of the swarms is such that, in the majority of territories concerned, opportunities for using large ground machines against the adults are rare. Against the earlier stages, on the other hand, the economics of large-scale baiting campaigns tend to favour the direct use of an insecticide concentrate, and the avoidance thereby of the heavy transport costs inevitable with bait. Serious consideration has accordingly been given to the possibilities of low-volume spraying equipment [3], capable of applying insecticide concentrates satisfactorily at a fraction of a gallon per acre, simple enough to continue to operate under conditions of intensive field operation with minimal maintenance, and cheap enough for use by the hundred or thousand.

One machine of particular interest in these respects is a simple exhaust sprayer, originally designed by H. J. Sayer, on which development work has subsequently been sponsored by the Sudan Government. Land-Rover exhaust gases are used to provide pressure (about 5 lb./sq. in.) to feed the spray liquid to a simple nozzle, at which atomization is effected by the gases emerging at high speed through a restricted annular orifice. With a mass median diameter in the 100 μ class, an emission rate of ¼–⅓ gal./min. at 3 m.p.h., and a price of the order of £10, the machine shows considerable promise as an economic means of applying concentrated insecticide. A satisfactory kill per gallon was obtained in an initial trial with 20% DNC against a roosting swarm, and excellent results have been obtained with dieldrin against egg fields prior to hatching. Against hoppers, especially the older instars, a concentrated formulation of a persistent stomach poison in a non-volatile solvent is required, and work on these lines is continuing.

Under suitable conditions (with hoppers grouped densely enough to be readily seen from the air, and in bands large enough to provide economic spray targets), spraying aircraft can very usefully reinforce ground control operations against the older hoppers; but in general it is the mobility of desert locust swarms themselves against which aircraft find their most effective application. The manner in which spraying aircraft can in fact maintain contact during periods of large-scale displacement of swarms was illustrated during the invasion of East Africa at the beginning of 1954. Locating targets entirely by air reconnaissance, and operating from ten successive bases extending for over 600 miles across Kenya and Tanganyika, the aircraft unit remained in continuous contact with the incoming swarms for nearly three months, until well after the beginning of breeding: spraying began as the first swarms entered Kenya, and took place on all save eight days of the following nine weeks.

Aircraft spraying has been undertaken against both settled and flying swarms, and field assessments of both types of operation over a wide range of conditions have provided evidence of the main factors affecting efficiency, in terms of locusts killed per unit of insecticide.

Settled locusts present the relatively straightforward problem of a ground deposit which can be defined, from laboratory data, as ½–1 gal./acre of concentrated insecticide [2]. The most elegant operations of this type on record are those in the Rukwa valley in Tanganyika in 1947, in which the Porton method of drift-spraying was applied against static populations of adult red locusts; in one operation nearly 2 square miles was 90% cleared of locusts by an overall dosage of 0·7 gal. of 20% DNC/acre. The spray was applied from heights of 150–300 ft., over ground markers giving an exact spacing of the spray runs, and using a substantial overlap between successive swathes to obtain a relatively uniform ground deposit. Desert locust targets are, however, rarely as static as red locust populations, and target demarcation by ground parties is practicable only in exceptional circumstances. Fortunately the swarms are usually readily visible from the air, even when settled, so that their location does not present any serious difficulty. No exact spacing of successive spray lines can, however, be expected without ground markers; and in recent trials in East Africa and Somaliland by D. J. McDonald (not yet published) it has been found necessary to use independent individual swathes, capable of giving satisfactory results without depending on overlap between runs. This has meant much lower spraying heights than in the Rukwa trials, a finer spray (minimizing overdosing), and, at wind speeds above 10 m.p.h. or so, spray runs into wind instead of across wind to obtain an adequate ground deposit.

Kills of settled locusts have reflected a very marked effect of the density of locusts in the target area. Thus, with 20% DNC results have ranged from 5000/gal. in the Rukwa operation against a target of 0·9 red locusts/sq. yd. to a kill of 220,000/gal. in Kenya in February 1955 against desert locusts settled at a density of about 70/sq. yd. in a roosting swarm. With 11% $\gamma$-BHC, kills on desert locust swarms have ranged from 48,000/gal. against a "very thin" swarm of 10 locusts/sq. yd. to 230,000/gal. against locusts at an estimated density of 60/sq. yd.

Against flying locusts, recent unpublished laboratory work by K. F. Sawyer and R. D. McCuaig has shown that it is necessary to apply roughly the same quantity of insecticide to the individual locust when it is in flight as when settled, but has confirmed earlier findings [11] that the locust is a more efficient collector of spray in flight than when settled. A fine spray is necessary for maximum pick-up by flying locusts, in conjunction with tactics enabling the spray to be emitted among the flying locusts within the swarm itself, in order to minimize spray losses by turbulence. Owing to the random movements of the flying locusts within the swarm, the position of successive spray-runs relative to each other is immaterial, and each may be put down through the densest concentration of flying locusts seen at the time.

Probably the most important single factor affecting the efficiency of spraying operations against flying locusts is, again, their spacing (in this case the volume density), which has been shown photographically to range from less than 0·01 to more than 10 locusts/cu. yd. A theoretical treatment [9] indicates that over the lower part of this range the kill from a given spray-run could be expected to be almost directly proportional to the volume density of the target swarm. Field indications of such an effect were provided by two detailed assessments, made during Sudan Government trials [5] in Kordofan in July 1954, in which a kill of 16,000 locusts/gal. of 20% DNC was recorded against a thin, scattered flying swarm, while against a denser and deeper swarm a kill of 52,000/gal. was obtained.

These results followed spraying on a scale which was small in relation to the size of the swarms concerned (10–30 gal./sq. mile); and there are indications that, when flying swarms are sprayed with DNC, rate and speed of application may also affect the kill per gallon. Thus, in northern Tanganyika in February 1954, a flying swarm of about two square miles was completely destroyed by the application of 600 gallons of DNC in one day, and a detailed assessment gave a kill of 350,000 locusts/gal. While high volume densities are also likely to have contributed to this result, it is probable that a substantial proportion of such a kill represents the cumulative effect of small doses of DNC due to successive spray-runs; but recent laboratory work [10] has shown that locusts can recover rapidly from small doses of DNC if these are not applied in sufficiently rapid succession. Thus a dosage sufficient to kill more than 99% of the locusts receiving it in a single application has been found to kill only about 40% when the same total amount is applied in four daily doses.

Contact kills of adult locusts by γ-BHC are much slower than by DNC, but in laboratory tests sub-lethal doses of the former have been found much more effectively cumulative than was the case with DNC [4]. In field assessments, kills of 100,000–300,000 locusts/gal. of 11% γ-BHC have been recorded following rates of application of 20–250 gal./sq. mile of high-flying swarms, some of them large.

While there still remain possibilities of substantial improvements in spraying technique, particularly against settled swarms, the best results so far recorded have been obtained by spraying at a stage when the target swarm included both densely settled and densely low-flying locusts. Thus kills of 380,000 locusts/gal. of 20% DNC, at El Fasher in June 1955 [6], and of 700,000/gal. of 11% γ-BHC, north of the Usambara mountains in March 1955, both followed the spraying of swarms which were partly settled and partly in flight, on and over the roosting site in the morning; and a kill of 740,000/gal. of 11% γ-BHC, in the Kenya Highlands in January 1953 [8], resulted from spraying a swarm flying low and very densely in the late afternoon only ⅔ mile short of its roosting site, when locusts are likely to have been temporarily settled in considerable numbers beneath the swarm.

In conclusion, attention may be drawn to the evidence, provided by detailed field assessments of baiting trials against hopper bands and of aircraft spraying operations against adult swarms, both settled and in flight, that the effects of locust behaviour on the differences in efficiency recorded within each method have been large compared with those of differences either in the insecticide used or in the equipment with which it was applied. It must therefore be emphasized that improvements in the efficiency of control operations against the desert locust require not only further developments of insecticides and equipment but also a better appreciation and understanding of the relevant aspects of locust behaviour.

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# MISTBLOWING IN ORCHARDS IN THE NETHERLANDS

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*Recent experimental work on the possibilities of mistblowing for the control of pests and diseases is briefly described in this paper, read at an international conference on plant protection held at Fernhurst Research Station in 1956. Mistblowing uses far less material than spraying and gives just as good results in orchards at about half the cost per acre. It is now becoming popular in Holland, and its wider use is expected.*

The cultivation of a healthy crop has always been the intention of the grower, and only when compelled by necessity does he apply chemicals and other means to control pests and diseases of plants. It is evident, therefore, that he will try to control or, better, to prevent pests and diseases with the least poisonous means in the smallest quantity at the lowest cost. Attention is drawn here to the possibilities of the mistblower for use in orchards, especially on small enterprises. The more usual means of spraying and the value and quality of spreaders and stickers are not dealt with.

The speedsprayer, which came into use in the United States as early as 1937, achieved an important saving in labour; but because the good is the enemy of the better, the mistblower was slower to be accepted in that country in spite of the research of Potts, Spencer and others. In the Netherlands, where the speedsprayer was almost unknown, the mistblower was tried for the first time in 1948, and after adopting the tenfold concentration the employment of the hand-operated mistblower, and in the last few years also that of the automatic mistblower, increased rapidly. Today the mistblower is considered to be the greatest improvement in the technique of pest and disease control of the last decade.

Returning to the fundamental side of plant protection, we can state that the poisonous materials have to be brought to the plant or into the soil in such a manner that, at all places where the parasites may attack the plant, just enough poison needed for control is applied. It follows that in general the poison should be distributed as uniformly as possible and preferably in the smallest particles.

Supposing that by mistblowing the average diameter of droplets is two-fifths that obtained with the sprayer, this means that with the same volume of liquid the number of particles will become $(2{\cdot}5)^3$ times as large. The surface covered by one droplet will decrease to $(\frac{2}{5})^2$, and that covered by all droplets will increase $(2{\cdot}5)^3 \times (\frac{2}{5})^2 = 2{\cdot}5$ times in comparison with the surface covered by the larger droplets when spraying. We may therefore accept that the chance of contact has increased about 15 times.

In spraying full-grown orchards 200–400 gal./acre is used; in mistblowing, only 10–20 gal./acre. The reason for this great difference is partly that by using the tenfold higher concentration the chance of run-off is much smaller than in spraying, and the particles remain as separate droplets on the plants. But because run-off is avoided and the small droplets stick better than large ones, the quantity of poison on the plant will be about the same in both methods.

The resulting protection in both cases is nearly identical. In mistblowing, however, the tenfold higher concentration and the lower quantity of liquid $(\frac{1}{15}-\frac{1}{20})$ give a saving of 30–50% of the quantity of poison and 90–95% of the quantity of water. Moreover, labour and transport costs are reduced.

The spraying method differs considerably when working with spray-guns or with hand-operated mistblowers. In using the hand-operated mistblower in orchards (as was worked out in the Netherlands by Dr. Bezemer, Mr. Houter and Mr. Wegenaar) the tree is the unit of treatment, for the mist is directed into the tree and not to its parts as in ordinary spraying. This difference, as well as composition of the chemicals and the fact that dosage in mistblowing is based on the time taken to treat each tree, have ensured the success of the mistblower in our country. Although it has been suggested that the good results of the hand-operated mistblower may be due to the moving outlet, it was proved in our orchards that a stationary outlet gave even better penetration. In automatic mistblowing the tree row is taken as the unit.

The most important point in applying pesticides to crops is that the drops reach the leaves and branches and stick there. Whether they get there depends mainly on the energy with which they are projected against the leaves in spraying, and on the air speed and the size of droplets in mistblowing. With increasing droplet size, greater air speed and less obstruction, the chance that the drops will settle down is also greater. This follows from the research of Brooks, who records that for droplets of 40 μ on cylinders ½ in. in diameter an air speed of 2¼ m.p.h. gave a catch of 30%, and at 72 m.p.h. nearly 90%. With droplets of 100 μ the catch at 2¼ m.p.h. was more than 70% and at 18 m.p.h. nearly 90%. If the cylinder had a diameter of ⅛ in. the catch of droplets of 40 μ at 2¼ m.p.h. was 66%.

In general, efficiency of control depends on thoroughness of coverage of the plants by the chemicals. The degree of coverage depends again on number and diameter of the drops. With a certain quantity of liquid to be sprayed, a dispersion into smaller drops will give a better coverage than dispersion into large drops.

Small drops follow the airstream more easily and deviate less from their course than larger drops, so that they reach the leaves more rapidly (Brooks). It is known that on branches and needles of firs and the like a smaller droplet size can be used than on leafy trees. With no wind and in woods smaller droplets may also suffice. In the Netherlands, which has a very windy climate, especially along the sea coast, this is not possible. This may also be concluded from the research of Brooks. He states that at a falling height of 10 ft. with a wind speed of 3 m.p.h. the drift amounts to 4 ft. for drops of 2 mm. (very heavy rain), 5 ft. for drops of 1 mm. (moderate rain), 7 ft. for drops of 500 μ (light rain), 19 ft. for droplets of 200 μ (drizzle), 48 ft. for droplets of 100 μ (mist), 409 ft. for droplets of 33 μ (cloud), and 3–4 miles for droplets of 5 μ (sea fog). Fogging is often inefficient because the minute droplets drift away on air currents without being deposited.

From these facts, and those concerning the air speed needed to ensure that the droplets reach and stick to the leaves, it follows that, even with a breeze, the wind speed at the place of settling has to be about 11 m.p.h. and considerably higher near the outlet, unless the trees are very small or the outlet very large.

Thoroughness of coverage in mistblowing is illustrated by the following example. Using 20 gal./acre at an average drop diameter of 80 μ (i.e. 3900 drops from 1 mm.$^3$) and spraying a plant surface five times the area of the ground, about 10,000 drops may be deposited on a square inch. Even if the average deposit is only one-third of this, this means about 500 drops on a 1 cm.$^2$ leaf surface. The average drop distance (unprotected space) is therefore about 380 μ. Assuming that two-thirds of the quantity is deposited on the plant, the average distance between the drops will be about 250 μ and the coverage about 5%. In practice this seems to be sufficient: in our apple orchards we obtained very good control by using 20 gal./acre both with insecticides and with fungicides.

In principle the best types of mistblower will be those which give the largest quantity of air with sufficient speed (pressure) to carry the droplets into the tree, and which require least power to achieve this. Because the diameter of the air stream also plays a part, there will be a compromise between this and the air speed in getting a certain penetration of the trees. The latter is dependent on the speed of working (moving of the mistblower) and on temperature conditions.

On the one hand the air stream of the mistblower serves as a transport medium for the drops; on the other hand it serves as a means of producing drops. The production of drops is obtained in several ways. From studies by Mr. Feis in our Institute it is to be expected that the best results may be obtained by expelling a liquid film by an air stream.

It has been proved that counting of droplets should not be done in a simple way, as on glass plates under the microscope. The main objections to such methods are that the rate of evaporation varies on different catching surfaces and they take a lot of time. An electronic counting apparatus developed by Burgestein, Feis and Businger at the Institute of Horticultural Engineering makes it possible (as does the earlier-developed instrument of Courshee at the N.I.A.E.) to measure the chords of droplets automatically and to count the drops in classes.

Economic comparison of the most important spraying methods can best be made in a full-grown apple orchard of nearly 80 trees/acre. Machine capacities may be rated as follows:

1. *Ordinary sprayer.* This sprays an average of ⅜ acre per man-hour, three men spraying. Capacity of the pump is 15 h.p.
2. *Hand-operated mistblower.* With one man at

COMPARISON OF COSTS OF TREATMENT USING DIFFERENT TYPES OF SPRAYERS AND BLOWERS IN AN ORCHARD OF 25 ACRES RECEIVING 12 APPLICATIONS A YEAR (CONVERTED FROM DUTCH PRICES, TAKING 1 DUTCH FLORIN = 2 SHILLINGS)

| | High-pressure sprayer £450 | | Speedsprayer with air propeller £790 | | Hand-operated mistblower £480 | | Automatic mistblower £540 | |
|---|---|---|---|---|---|---|---|---|
| | | £ s. | | £ s. | | £ s. | | £ s. |
| Depreciation (10%) . . | | 45 0 | | 79 0 | | 48 0 | | 54 0 |
| Interest (3½% of 60%) | | 9 10 | | 16 10 | | 10 0 | | 11 10 |
| Maintenance/repairs . . | | 10 0 | Sprayer £10<br>Set £20 | 30 0 | | 10 0 | | 6 0 |
| Fixed cost of sprayer . . | | 64 10 | | 125 10 | | 68 0 | | 71 10 |
| Fixed cost of tractor . . | 360 hr. @ 5s. | 90 0 | 180 hr. @ 5s. | 45 0 | 170 hr. @ 5s. | 42 10 | 120 hr. @ 5s. | 30 0 |
| Fuel for tractor . . | 360 hr. @ 1½s. | 27 0 | 180 hr. @ 1½s. | 13 10 | 170 hr. @ 1½s. | 12 15 | 120 hr. @ 1½s. | 9 0 |
| Fuel for set . . . . | | | 180 hr. @ 1s. | 9 0 | | | | |
| Spraying liquid . . | 12×25 ac. @ 350 gal. @ 1d./gal. | 437 0 | 12×25 ac. @ 250 gal. @ 1d./gal. | 312 10 | 12×25 ac. @ 20 gal. @ 10d./gal. | 250 0 | 12×25 ac. @ 20 gal. @ 10d./gal. | 250 0 |
| Labour . . . . | 3×360hr. @ 3s. | 162 0 | 180 hr. @ 3s. | 27 0 | 2×170hr. @ 3s. | 51 0 | 120 hr. @ 3s. | 18 0 |
| Total cost/year for 25 acres | | £780 10 | | £532 10 | | £424 5 | | £378 10 |
| Cost acre/year . . . . | | £31 0 | | £21 0 | | £17 0 | | £15 0 |

the tractor and one spraying, 1 acre per man-hour is done. Capacity of the sprayer is 5–12 h.p. and that of the tractor is 10 h.p.

3. *Speedsprayer with air-propeller*. Rate of spraying is 2½ acres per man-hour, the tractor-driver having to ride and fill. Capacity of the pump is 15 h.p., that of the tractor 24 h.p.; driving the air-propeller demands 20 h.p.
4. *Automatic mistblower*. This treats 5 acres per man-hour. Capacity of the pump is 2 h.p., of the ventilator 10 h.p., of the tractor 18 h.p. (In mistblowing a banana plantation for the control of the Sigatoga disease, using a special K.W.L. (Kiekens-Whirlwind-London) mistblower having 6 outlets on top of a tube 8½ m. high, drawn by a crawler, a capacity of 10–25 acres a man-hour was reached.)

The table gives a comparison of the different types of blowers and sprayers, obtained in an apple orchard of 25 acres. This shows that the cost of treatment by mistblowing is about half that of ordinary spraying. Assuming a production per acre of 16,000 lb. of apples and a price of 4d. a lb. for the first grade and 2d. a lb. for the second, it would take an increase in high-grade fruit of only 11–12% to pay for the cost of mistblowing.

To sum up, in comparison with high-volume spraying, mistblowing uses half the amount of poisonous material, owing to the absence of run-off and better deposition of the drops. Labour is also much reduced, because less liquid has to be transported.

We expect that mistblowing will be applied more generally in the near future, despite the fact that in working with smaller droplets the chance of deposition becomes relatively less.

# BOOK REVIEWS

**The Manuring of Sugarcane.** D. J. Halliday. Pp. 221. Centre d'Etude de l'Azote, Geneva. 1956.

An enormous number of experiments have been made on the manuring of sugar cane, as well as of other crops. The results are scattered through a hundred scientific publications which are seldom read by practical growers. Indeed, the published results of any trustworthy modern manurial experiment would be almost meaningless to the majority of growers. Each experiment produces some small piece of new knowledge, of little or only local use by itself, but forming a part of the total picture of our knowledge of the nutrition and cultivation of sugar cane. One of the great problems of applied agricultural science is how to present such a picture to the farmer and the grower.

In this book, issued by the Centre d'Etude de l'Azote, are summarized over 600 papers dealing with manurial experiments carried out in all the cane-growing countries of the world. Short accounts are given of the history of cane cultivation, and of the cultural and nutrient requirements of the crop, but the main part of the book comprises concise, factual summaries of the results of manurial experiments in 24 different countries or regions. These should be extremely useful to growers as well as fertilizer manufacturers, though perhaps the condensation of these already highly condensed summaries into a final general summary in which, for example, the fertilizer requirements of India's 1·5 million hectares of cane-growing land are given in one sentence, has been carried too far. This summary of some 2000 words is also given in French and German. One could perhaps summarize this summary into the statement that everywhere sugar cane responds to nitrogen, and in many places to phosphorus and potassium. If the reader wants a general picture of fertilizer requirement in any cane-growing country he can obtain it in the main body of the book, and if he wants precise details he can refer to the original papers listed in the full and excellent bibliography that is provided.

The book is well, but very extravagantly, produced. There are too many blank spaces on its pages, some of the maps are useless (it is unnecessary to print a full-page outline map of Africa to show that sugar cane is grown in Egypt and Natal), and many of the otherwise excellent illustrations have no connexion with the matter of the text. Anybody who wishes to find any data or any source of data on the manuring of sugar cane anywhere can find them without much difficulty in this book, but he could have found them even more easily if some of the frills had been left out.

G. V. JACKS

**Losses caused by Plant Diseases in the Colonies.** (Commonwealth Mycological Institute Phytopathological Papers No. 1.) G. Watts Padwick. Pp. 60, with line and half-tone illustrations. Commonwealth Mycological Institute, London. 1956. 10s. net.

Up to about 1940 the term "economic mycologist" merely meant a person who studied the diseases of economic crops, and in this study there was generally far more mycology than there was economics. Since the war, however, a small but increasing band of enthusiasts have realized the vital importance of economic information on the subject of disease losses in crops. In place of vague generalizations, such as "severe attacks" or the all too easy "ten per cent," we now have serious studies of crop losses from disease. With only limited resources available for fighting disease we urgently need to know which diseases are causing the most severe losses in order that these resources may be used to the best advantage. Dr. Padwick's paper is an excellent study of the losses to crops from diseases in the British Colonies and an example of what can be achieved by correlating all the available information—that from the literature, that from personal experience and consultation with fellow mycologists, and that obtained from a special survey made by the Colonial Insecticides, Fungicides and Herbicides Committee.

In a short thirty pages of text Dr. Padwick gives a very clear account of the whole subject. He examines the difficulties inherent in loss assessment and gives his methods of overcoming them. He instances the differences of treatment needed in dealing with plantation and field crops, and the differences between the killing diseases and the debilitating ones, including attack arising in vegetatively produced crops and in those grown from seed.

Most important of all, the author gives his estimate of disease losses in each crop. This is a matter of no small difficulty, and he overcomes most of it. For instance, he indicates a comparatively simple mathematical treatment which overcomes the absurdity of merely adding up loss estimates irrespective of their interaction, one on the other. In the final result it is interesting to note the wide range of crop losses that occur: for instance, in pulse crops the loss averages 5·4%, whereas in stimulants, drugs and spices it rises to 25·9%, and the weighted average of loss on all crops in the Colonial territories is 11·8%.

This well-produced and documented pamphlet should be read by anyone interested in the future of agriculture in any territory, for assessment of the amount of damage being done by plant diseases is an essential step in any practical measures to be adopted for overcoming them. It is to be hoped that it will form a model for similar studies in other fields—for instance, the same thing needs to be done for the Dominions and for the United Kingdom, and the entomologists have the whole area open to them and should follow the example set by this mycological paper. There is only one regret: that it has taken two years for this paper to reach publication.

G. ORDISH

**Tobacco Diseases: With Special Reference to Africa.** J. C. F. Hopkins. Pp. 178, with half-tone and colour illustrations. The Commonwealth Mycological Institute, Kew, Surrey. 1956. 35s. net.

The appearance of Dr. Hopkins's book is most welcome. It has been long awaited and will fulfil an important need. The author was for many years associated with the Rhodesian tobacco industry, and this book is an extension of his *Diseases of Tobacco in Southern Rhodesia* published in 1931 and its supplement issued in 1939. It is now a most comprehensive account of the diseases and disorders that have been known to afflict the tobacco plant in Africa.

The standard of production is good, and the illustrations are adequate. In presentation an attempt is made to give a practical account of the diseases, suitable for growers, without neglecting fundamental problems in their study. To a large extent the author has been successful. The inclusion of an identification key, based on symptoms, would have been a help to growers, and more stress might have been placed on points of similarity between certain diseases, notably leaf spots.

The emphasis throughout the text in placing first reliance on simple controls, such as destruction of infected material, must be commended; control by chemical means or by growing resistant varieties should be complementary to the use of hygienic measures.

The case for "priming," as a method of controlling leaf-spot diseases, is neatly summed up, though the experimental results obtained by Stephen in Rhodesia are not mentioned, presumably having appeared too late for incorporation. It is true that in some areas of East Africa leaf-spotting diseases appear almost absent; but that cannot be credited to "priming," for many growers omit the operation.

Recent work, again by Stephen, has shown that the relationship between nitrogen and frog-eye infection is more complex than suggested here. Although a nitrogen-deficient plant may exhibit more spots in the field, this is not necessarily the most important point. If curing methods are not satisfactory an adequate dressing of nitrogen can give rise to a cured leaf much more heavily spotted than one produced without nitrogen.

The remarks on deficiency symptoms need qualification. It is certainly possible to have acute phosphate deficiency symptoms—in fact, in parts of East Africa Virginia-type varieties will fail completely in the absence of added phosphates. Similarly the implication of a positive phosphate × potash interaction has not been conclusively proved in Africa, and the symptoms of supposed potash deficiency shown in Fig. 79 have been noted on plants which had received 120 lb. $P_2O_5$ and 100 lb. $K_2O$ per acre.

These criticisms detract little from a most useful publication which should find its way to the bookshelves of all those connected with the growing of tobacco, particularly in Africa. B. C. AKEHURST

**The Chemistry and Mode of Action of Plant Growth Substances.** (Proceedings of a Symposium held at Wye College, University of London, July 1956.) Edited by R. L. Wain and F. Wightman. Pp. xi + 312, with line and half-tone illustrations. Butterworths Scientific Publications, London. 1956. 55s. net.

Attendance at conferences is perhaps the easiest and most pleasant way of keeping up to date in any rapidly advancing branch of science. The next best thing is to read the published proceedings. This book presents in full the 26 papers delivered at the Fourth Conference on Plant Growth Substances, and it will be of much value to all engaged in research work on this subject.

Few fields of biological endeavour are enlarging so rapidly. New techniques, such as paper chromatography, continuously expand its borders and make more fundamental studies possible. Frequent progress reports, such as those in this book, are therefore essential, not only to keep the research worker abreast of the times but to reveal the shortcomings of past work and to indicate more fruitful lines for investigation.

The subject matter is classified into four sections. The first, comprising seven papers on natural auxins, begins appropriately with a critical study of processes involved in auxin bioassay; methods of extraction, chromatographic techniques and reliable and sensitive methods of bioassay are described. This account should be perused by all who intend to use this type of bioassay. Other papers concern the estimation of plant growth hormones in germinating seeds and the nature and biogenesis of their precursors. A paper on problems involved in studies of geotropism completes this section.

In the second section nine papers deal with the relation between the structure of a wide range of organic compounds and their biological activity on plants. One of them describes a tissue culture study of particular interest in that it enables a distinction to be made between the effects of growth regulators on cell elongation and cell proliferation. A further paper outlines a satisfactory resolution of optically active acids.

Metabolism and mode of action is the subject of the third section, and its seven papers include some interesting work showing how auxin treatment causes metabolic disturbances and influences water and salt uptake. The book concludes with two studies on the kinetics of auxin-induced growth.

The work is excellently produced, well illustrated with figures and tables, and well documented. Its main defect is that some of the discussions which took place after each paper are not recorded. It constitutes one of the best reviews of work on this subject up to 1955. R. C. BRIAN

# ABSTRACTS

## CROP PRODUCTION

**The effects of very deep ploughing and of subsoiling on crop yields.** E. W. Russell, *J. agric. Sci.*, 1956, **48**, 129–44.

Ploughing to a depth of over 12 in. caused subsequent difficulties if the subsoil was pure sand or contained much stone, or if the water table was high; on the other hand, it generally gave better control of weeds than shallower ploughing and sometimes on heavy soil gave a much drier soil surface in early spring. Ploughing to a depth of over 12 in. or subsoiling to a depth of about 18 in. increased yields in 51% of the experiments with sugar beet, 44% of those with cereals and 37% of those with potatoes, decreased yields in 26% of the experiments with sugar beet, 18% of those with cereals and 22% of those with potatoes, and had no effect on yields in 23% of the experiments with sugar beet, 38% of those with cereals, and 41% of those with potatoes. On clays and loams there was little difference between deep ploughing and subsoiling; about half the fields gave an increase of yield due to deep tillage. On sands subsoiling (with or without deep ploughing) increased yields in about a third and decreased yields in about a quarter of the fields; deep ploughing by itself decreased yields in about 40% of the fields and seldom gave much benefit. On light loams subsoiling increased yields in about half the fields; subsoiling and deep ploughing tended to give better results than subsoiling alone. S.F.A.

**Ammonia liquor as a nitrogenous fertilizer.** H. Tod and K. Simpson, *J. Sci. Fd Agric.*, 1956, **7**, 511–16.

In 1954 raw ammonia liquor from four gasworks was compared with ammonium sulphate on grassland at four centres in Scotland; the sulphate was broadcast by hand and the liquor applied from watering cans. There was little scorch from ammonium sulphate, but the ammonia liquor caused considerable scorch at three centres, though most of the grass recovered. Mean production of crude protein in lb./acre was: ammonium sulphate (56 lb. N/acre), 148; ammonia liquor (28 and 84 lb. N/acre), 10 and 71. In 1955 ammonia liquor was applied at one centre from jets 7 in. apart; this largely overcame scorch. Average crude protein production from applications of 56 lb. N/acre was, in lb./acre: ammonium sulphate, 103; 'Nitro-Chalk,' 103; ammonia liquor, 68. Concentrated ammonia liquor (total N 12·7%) was injected into the soil in trials on potatoes and swedes in 1955. On potatoes ammonium sulphate and the lower rate of ammonia liquor had no significant effect; ammonia liquor at 112 lb. N/acre reduced the yield. Swedes showed a slight response to nitrogen; the production of crude protein was the same from ammonia liquor and ammonium sulphate plots, although the higher rate of ammonia liquor (56 lb. N/acre) depressed total yield. S.F.A.

**Factors affecting the uptake of phosphorus by crops in south-east Scotland.** K. Simpson, *J. Sci. Fd Agric.*, 1956, **7**, 745–53.

Over 50 field experiments were carried out between 1941 and 1955 with the objects of comparing superphosphate with other phosphate fertilizers, correlating the amount of phosphorus recovered by swedes, and estimating the residual effects on the following crop. Yields of swedes, oats and potatoes were considerably increased by moderate amounts of phosphate, but the response of grass was poor. Superphosphate was the best phosphate fertilizer; ammoniated superphosphate, dicalcium phosphate and basic slag were about 20% less effective; silicophosphate and nitrophosphate were about 25% less effective; finely ground Gafsa mineral phosphate was of little use, even in the wetter areas. A dressing of 4 cwt. superphosphate (90 lb. $P_2O_5$) per acre is recommended for swedes. Soil factors that tended to increase the recovery of phosphorus from superphosphate were high exchangeable calcium and low readily soluble phosphorus; the effect of *p*H was variable. There was no relationship between spring rainfall and recovery of phosphorus, but high rainfall in May–October increased phosphorus recovery. This effect is attributed to high yields from control crops in dry summers due to increased availability of soil phosphorus, which in turn may be caused by higher soil temperatures in dry seasons; drought was not considered to be a limiting factor to crop growth in these experiments. S.F.A.

**Potassium frit as a special-purpose fertilizer.** O. R. Lunt and B. Kwate, *Soil Sci.*, 1956, **82**, 3–8.

A potassium frit containing about 36% $K_2O$, produced by fusing orthoclase feldspar and $KNO_3$ or $K_2CO_3$ at about 2200° F and then air quenching, had a high weathering rate and low solubility. Two figures are given to show that the degree of solubility is increased by fineness of grinding and weathering rate in soil. From three tables it is seen that application of frit increases soil *p*H, probably owing to silicate ions going into solution. In culture studies with tomatoes, barley and carnations the frit is shown to be a readily available source of potassium, and in large applications it can supply potassium over long periods without producing a salinity problem. The frit would appear to be of particular value under conditions where leaching losses from usual sources of potash can be exceptionally great. E.M.A.

**Some effects of a soil conditioner on a heavy and a light soil in Aberdeenshire.** J. Pringle and M. T. H. Williamson, *J. Sci. Fd Agric.*, 1956, **7**, 540–5.

A description is given of pot experiments carried out to find the effect of the soil conditioner vinyl acetate maleic acid anhydride polymer (CRD-186) on the germination of wheat on two soils: a silty clay loam ley soil (26·4% clay; *p*H 5·4) and a sandy clay loam arable soil (21·9% clay; *p*H 5·5). Three tables show the effect of CRD-186 on germination and soil condition, on water losses from the cropped pots and on the content of water-stable aggregates. Best germination and growth rates were obtained in the treated arable soil; the untreated ley soil gave better results than the treated. The increase in water-stable aggregates was greatest in the treated arable soil also. In field trials the Merloam formulation of the soil conditioner was applied and raked into the seedbed before sowing carrot. No increase in carrot yield was obtained, but germination was earlier and growth was better throughout the growing season. June and September soil samples showed significant increases in the number of water-stable aggregates in treated soil, and results indicated that applications of the polymer to give 0·05–0·1% in the top 3 in. of soil was the optimal dressing on the arable type soil. E.M.A.

**Effect of sulphur and gypsum additions on availability of rock phosphate phosphorus in Leon fine sand.** J. R. Neller, *Soil Sci.*, 1956, **82**, 129–34.

Sulphur had been shown to be essential for legume growth on the sandy acid soil under test, which in its virgin state is deficient in phosphorus. This experiment, designed to find the effect of sulphur on availability of ground rock phosphate, was carried out in 2-gallon glazed jars planted with Hubam clover and oats. Ground rock phosphate at 1000 lb./acre was mixed into the top 4 in. of soil, which had been limed to range from *p*H 7·3 (unsulphured) to *p*H 4·8 (sulphured). Before applying the rock phosphate it was mixed with sulphur at the rate of 200–1600 lb./acre; gypsum at 100 lb./acre was also used. Available residual phosphorus in rock phosphate was determined by radioactive tracer technique. Sulphur at 200–800 lb./acre gave highly significant growth increases, but 1600 lb./acre retarded growth. Gypsum at the rate applied was without effect. At *p*H 6·5 sufficient phosphorus was available for satisfactory growth of both clover and oats; at *p*H 5, however, growth of clover was seriously retarded and that of oats moderately so. The phosphorus of the residual rock phosphate was 13% more available in sulphured than in unsulphured soils. E.M.A.

**The effect of some factors on growth, development and yield of winter wheat.** J. C. Holmes and W. M. Tahir, *J. agric. Sci.*, 1956, **48**, 115–23.

The effects of spacing, nitrogen level, time of nitrogen application, and weed control on tillering, number of ears, plant height, weed population, yields of grain and straw, and nitrogen content of grain were studied in a one-year experiment near Edinburgh in 1951–52. Wide spacing increased tillering, but the yield of grain per acre was less. A high nitrogen level increased the number of tillers, the percentage of tillers bearing ears, and the nitrogen content of the grain. Late application of nitrogen did not affect grain yield but reduced straw yield and increased the nitrogen content of the grain. In the experiments on spacing and nitrogen level, weed control increased the grain yield, especially with wide spacing; in the experiment on nitrogen timing weed control increased the grain yield with early (6th March) and late (11th June) applications, but decreased the yield when nitrogen was applied at the start of tillering (9th April). S.F.A.

**Cereal manuring in England and Wales.** B. M. Church, *J. Sci. Fd Agric.*, 1956, **7**, 711–21.

The paper presents information collected on the manuring of cereals in the course of 40 surveys carried out in 27 districts of England and Wales from 1950 to 1954. In the case of nitrogen 0·6 cwt. N/acre (3 cwt. sulphate of ammonia) has been calculated as the optimum dressing; the average ranges from 0·25 to 0·35 cwt. N/acre—the lower rate for barley and oats, the higher for wheat; one-third of the cereal acreage received no N. For winter cereals about one-third of the nitrogen is applied in autumn in the seedbed, and in arable districts about two-thirds of the winter cereals and one-third of the spring cereals are top dressed with N. Phosphatic fertilizers are applied on cereals at rates above the average optimum of 0·1–0·3 cwt./acre $P_2O_5$. Rates for potash are about the optimum of 0·3 cwt./acre $K_2O$. Three-quarters of the phosphates and potash applied to cereals, including all that combine-drilled, is used in the form of compounds, and the increased usage of this type fertilizer on cereals leads to one-sixth of the $P_2O_5$ and one-quarter of the $K_2O$ on winter cereals being applied as top-dressings. About one-half of the phosphatic and potassic fertilizers used in the seedbed are combine-drilled. Also discussed are regional differences, effect of previous cropping, and varieties grown. It is stressed that profitable increases in the use of N on that part of the cereal acreage which receives little or no N would increase the total cereal yield in England and Wales by about 6%. E.M.A.

**Malting barley from winter-sown spring varieties.** H. J. Mason and A. E. Cox, *Agriculture, Lond.*, 1956, **63**, 315–18.

It is emphasized that best results with malting barley can be obtained only on well-drained soils in a state of high fertility. The advantages of growing spring varieties of barley in autumn are enhanced quality, greater capacity to withstand drought, earlier maturity, availability of labour, no loss of seed should autumn drilling be prevented, and less damage by mildew, and these are set against the disadvantages of greater risk of injury by frost and wheat bulb fly, increased incidence of take-all and eyespot, and increased weed growth caused by prevention of stubble cultivation. It is suggested that winter barley is most successful as the second corn crop in a rotation, and suitable varieties are said to be Spratt Archer, Plumage Archer, Proctor and Carlsberg. Seed rates depend on soil conditions: on light medium soils rates as for spring barley can be used; on heavier types, with October or November drilling, rates can be increased by ½ bu./acre. Too thick sowing, which inevitably leads to spindly growth and weak plants falling prey to frost, should be avoided. A sowing depth of 1–1½ in. is said to be ideal. Time of sowing is also very important; mid- or late December is considered best for fertile light soils. Fertilizer can be combine-drilled with the seed, and top-dressings of nitrogen in the form of ammonium sulphate or 'Nitro-Chalk' at 1 cwt./acre applied in both February and either late April or May. E.M.A.

**Sugar beet manuring. A re-examination of the experimental data.** D. A. Boyd, *Brit. Sug. Beet Rev.*, 1956, **25**, 19–22.

New recommendations are made for the manuring of sugar beet based on a re-examination of the results of the 360 experiments carried out from 1934 to 1949. The first step in this new survey was to separate out results from some 200 sites with fairly standard cropping history and normal cultivations, being on old arable land following a cereal crop and without farmyard manure. The sites with special characteristics warranted separate consideration. The importance of nitrogen and potash (or salt) and the relative unimportance of phosphate is stressed. Nitrogen is recommended at rates of 1·0–1·2 cwt./acre for old arable land and a wide range of soils, the higher rates where tops are utilized for stock feed. Less N is needed on dunged fields, and after a ley grazed or old grass the dressing should be halved. On true fen peat soils little N is needed, and dressings above 0·4 cwt. N/acre usually reduce yields. The optimal dressing for potash, except on deficient soils, appears to be 1·5 cwt. $K_2O$/acre. On heavy chalky boulder clays little or no potash is needed and 1·2 cwt. $K_2O$/acre has actually reduced yield. Where farmyard manure is applied potash dressings can be cut by about 0·6 cwt. $K_2O$/acre. There is a tendency for more phosphorus to be applied than is necessary, there being little benefit from more than 0·5 cwt. $P_2O_5$/acre except on peat soils and on chalky boulder clays and acid soils, where 1·0 cwt. $P_2O_5$ can be used to advantage; but the phosphorus dressing can be omitted on dunged soils. Salt gives an economic return on most soils, even in the presence of potash; without potash, salt is recommended at the rate of 5 cwt./acre. A 9-6-18 compound fertilizer is suggested as suitable for the sugar beet crop provided that the N balance is made up by an early top-dressing. E.M.A.

**Plant distribution and its effect on yields. Two years trials reviewed.** D. C. G. Thomson, *Brit. Sug. Beet Rev.*, 1956, **25**, 69–71.

Four methods of thinning sugar beet were compared: (1) uniform spacing, (2) normal hand singling (one-eighth irregularity), (3) twice through with a mechanical thinner followed by hand-hoeing (half irregularity), (4) twice through with a mechanical thinner with no subsequent hand work (complete irregularity). At equivalent plant populations there was no significant difference in yield between uniform spacing and normal hand singling; the losses in yield from the third and fourth methods of thinning were, respectively, 2¼ and 4 cwt. sugar per acre (½ and 1 ton/acre clean beet). The loss in yield due to irregularity of spacing could be counterbalanced by increasing the plant population; similar sugar yields were obtained from hand singling at 15 in. mean spacing (22,000 plants/acre) and mechanical thinning only at 9 in. mean spacing (34,000 plants/acre). S.F.A.

**Intervals of superphosphate application to downland permanent pasture.** M. J. T. Norman, *J. agric. Sci.*, 1956, **47**, 157–71.

Fenced plots in a pasture at Hurley were treated with all combinations of 0, 3 or 9 cwt./acre superphosphate (19% $P_2O_5$), applied in a single dose in March 1952, in three doses (March 1952, 1953 and 1954), or in nine doses (March, June and September of 1952, 1953 and 1954), and either no potash or 3 cwt./acre muriate of potash in three doses (1 cwt. each March). All plots received 62 lb. N/acre/year as 'Nitro-Chalk.' The plots were grazed simultaneously by sheep. Total dry matter and crude protein yields were higher from a single initial application and from thrice-yearly applications than from annual applications; this is attributed to seasonal changes in dry matter yield and phosphate content of herbage and of availability of phosphate (favouring thrice-yearly applications) superimposed on phosphate deficiency (favouring a large initial dose). Superphosphate affected favourably the cover of *Dactylis glomerata*, *Festuca rubra*, *Arrhenatherum elatius*, *Poa trivialis*, *Holcus lanatus*, *Lolium perenne* and *Trifolium repens*, had no measurable effect on *Poa pratensis*, *Plantago lanceolata*, *Ranunculus bulbosus* and *Crepis capillaris*, and affected unfavourably *Agrostis stolonifera*, *Leontodon* spp., *Prunella vulgaris* and other minor herbs. S.F.A.

**The influence of sward composition and sward management on the following oat crop.** R. Hughes and D. J. Griffiths, *J. Brit. Grassl. Soc.*, 1956, **11**, 147–54.

Sward composition had little effect on the following oat crop, but grazing (by sheep) was markedly superior to hay management. Manuring increased the production of grass; the consequent higher rate of stocking gave a better oat crop, but the higher hay yield depleted the soil and was followed by a slightly poorer oat crop than that following hay which had not received fertilizer. S.F.A.

**The yields and composition of lucerne, grass and clover under different systems of management. II.** W. E. Davies and R. O. Davies, *J. Brit. Grassl. Soc.*, 1956, **11**, 127–38.

Four cuts in the first harvest year gave considerably lower annual output in the first two years than two or three cuts in the first harvest year; in the third and fourth harvest years there was no significant difference between the plots, but the total yield over four harvest years depended on the frequency of cutting in the first year. Highest yields of dry matter and of crude protein over the four years were obtained with lucerne alone; intermediate yields were obtained from lucerne/grass/clover, lucerne/ryegrass, lucerne/cocksfoot, lucerne/white clover, and red and white clovers/grass; lower yields were obtained from red clover alone and grass alone. Residual fertility, measured by growing rape and turnips, was highest after lucerne and lucerne/ryegrass. S.F.A.

**On the variations in contents and inter-relations of minerals in dandelion (*Taraxacum officinale* Weber) and pasture grass.** F. K. van der Kley. *Neth. J. agric. Sci.*, 1956, **4**, 314–22.

Comparisons are made of the mineral composition of dandelions and grass grown under identical conditions on various soil types. Thirty-four samples of grass and dandelions were made from 15th to 30th May from paddocks of differing levels of fertility on moist sandy soil and Rhine clay. Tables give the mean and range of values of mineral content in dry matter, and diagrams illustrate base, acid base and alkalinity relationships. The importance of dandelions in pastures on animal health is discussed: the bases in dandelions safeguard against tetany, and the high copper content helps to prevent hypocupraemia. But lower yields, starch equivalent and digestible protein lessen the agricultural value of dandelions.

E.M.A.

## PLANT PROTECTION

**The effect of organophosphorus insecticidal sprays on the growth and phosphorus content of brussels sprouts.** G. N. Thorne, *Ann. appl. Biol.*, 1956, **44**, 499–505.

Although it has been stated that organophosphorus insecticides sometimes increase yields more than can be attributed to the control of insect pests, field experiments conducted at Rothamsted Experimental Station with schradan and demeton gave no evidence that this was so. The dry weight of brussels sprouts plants grown in soil supplying little phosphorus was unaffected by spraying 6 times with the insecticides, or with sodium phosphate solution supplying the same amount of phosphorus as the insecticides. The dry weight of larger plants grown in soil supplying more phosphorus was unaffected by spraying with the insecticides. (Schradan sprays decreased the dry weight in one experiment but not in another.) Spraying with schradan, or with the phosphorus equivalent as sodium phosphate, increased the phosphorus content of plants in one trial in which the soil supplied little phosphorus. With high phosphorus supply in the same experiment, sodium phosphate solution (but not schradan) increased the content of the plants slightly. Phosphorus content was unaffected by demeton sprays. D.L.

**Experiments on the control of the tropical fig borer in Israel.** I. Peretz and A. Avigdorov, *FAO Plant Prot. Bull.*, 1956, **4**, 132–5.

In parts of Israel more than half of the fig trees have been killed by the tunnelling of the fig borer *Batocera rufomaculata*. Young larvae destroy the bark and phloem of the lower part of the trunk, and older forms riddle the wood. In field trials best control was obtained when the bark overlying young larvae was painted with a plastic wax formulation containing parathion (2·5% active ingredient). Lindane used similarly gave equally good control but caused some injury to the bark. Demeton, diazinon, dieldrin, and malathion were less effective. Older tunnelling larvae were killed by injecting benzine into the tunnels, but such action is suggested only as a complementary treatment. D.L.

**Inhibition of *Venturia* spp. by analogues of host metabolites.** D. S. Kirkham and A. E. Flood, *Nature, Lond.*, 1956, **178**, 422–3.

In a search for host metabolites of the apple of greater antifungal activity and less damaging to the plant than chlorogenic acid, a series of seven structural analogues was examined *in vitro*. Of these, cinnamic acid proved most inhibitory to the apple scab fungus *Venturia inaequalis*, and was unique in that it prevented spore germination. Sporulation was inhibited by *o*-coumaric acid and *p*-coumaric acid, and slightly by protocatechuic acid. Quinic acid, a component of chlorogenic acid, had no effect on growth or sporulation. Similar results were obtained with *V. pirina*, the pear scab fungus. Cinnamic acid was tested *in vivo* on inoculated shoots of Cox's Orange Pippin, 0·2% solution of sodium cinnamate being injected 24 hours after inoculation. Only slight interveinal chlorosis and growth inhibition of the host resulted, despite an intake of about 100 mg./shoot tip. Thirteen days after inoculation a high degree of inhibition of *V. inaequalis* was observed on treated shoots, and the persistence of the cinnamate was ascertained chromatographically. D.L.

**Wirkung von antibiotikumhaltigen Kulturfiltraten von Angehörigen der *Streptomyces-albus*-Gruppe auf den Apfelmehltau und Spinnmilben *in vivo*. (Action of antibiotic-containing culture filtrates of the *Streptomyces albus* group on apple mildew and mites *in vivo*.)** H. Köhler and R. Fritzsche, *Anz. Schädlingsk.*, 1956, **29**, 65–8.

In the course of trials with antibiotically active cultural filtrates of a *Streptomyces* strain of the *albus* group against apple mildew (*Podosphaera leucotricha*) it was found that the material acted not only as a fungicide but that it was also acaricidal. In the field it controlled *Metatetranychus pilosus* and *Bryobia praetiosa*, and in laboratory trials it reduced populations of *Tetranychus althaeae* by 90% in 4 days.

D.L.

**The nature of the resistance of oats to the take-all fungus II. Inhibition of growth and respiration of *Ophiobolus graminis* Sacc. and other fungi by a constituent of oat sap.** E. M. Turner, *J. exp. Bot.*, 1956, **7**, 80–92.

A partially purified substance from the sap of oat leaves inhibited the growth of the take-all fungus *Ophiobolus graminis* and its variety *avenae*, at concentrations of 3·3–4·0 µg./ml. Respiration was inhibited by concentrations of 55 µg./ml. Sap extracted from oat roots was inhibitory only to *O. graminis*, and fractionation of the sap showed that the inhibitor could be masked by a growth stimulant. The susceptibility of oats to *O. graminis* var. *avenae* is considered to be due to conditions enabling the fungus to overcome toxicity rather than to an absence of toxicity. Other fungi were also inhibited by the substance, but none was as sensitive as *O. graminis*. D.L.

**The production of antibiotics in soil. IV. Production of antibiotics in coats of seeds sown in soil.** J. M. Wright, *Ann. appl. Biol.*, 1956, **44**, 561–6.

It has been assumed that antibiotics play a part in the relationships between constituents of the soil microflora and in the control of plant diseases, for attempts to control diseases by the inoculation of seeds with saprophytic antibiotic-producing organisms have met with some success *in vitro*. The assumption has now been proved. Gliotoxin was detected in the coats of uninoculated pea seeds, sown in soil in which a gliotoxin-producing strain of *Trichoderma viride* was growing vigorously. Extracts of the coats of seeds inoculated with *T. viride*, *Penicillium frequentans* or *P. gladioli* and sown in soil were found to contain gliotoxin, frequentin and gladiolic acid respectively. No antibiotic was produced in seed coats from three species of *Streptomyces*. D.L.

**Preliminary note on the downward movement of streptomycin in apple and pear tissues.** J. C. Dunegan and R. A. Wilson, *Plant Dis. Reptr*, 1956, **40**, 478.

In the course of experiments on the translocation of introduced streptomycin in apple and pear it was discovered that downward movement was possible with this antibiotic or its by-products. High concentrations of streptomycin were introduced by wicks threaded through punctures made in the petiole at the base of the leaf-blade. Vascular symptoms developed first on leaves at the growing point, 4–8 nodes above the treated leaf; subsequently symptoms appeared on leaves 2–4 nodes below the treated leaf. D.L.

**Studies in the treatment of potato seed pieces with antibiotic substances in relation to bacterial and fungous decay.** R. Bonde and J. F. Malcolmson, *Plant Dis. Reptr*, 1956, **40**, 615–19.

Of several antibiotics and antibiotic formulations examined as protectants for potato seed pieces, those containing streptomycin sulphate, streptomycin nitrate, and terramycin hydrochloride gave total control of bacterial soft rot caused by spray inoculation with *Erwinia atrospetica*. Treatment consisted of dipping the seed pieces for 1 minute in 100 p.p.m. concentrations of the antibiotics before inoculation. The field stand was 100% from treated pieces, compared with 35% from controls. Agrimycin 100 (streptomycin plus terramycin) gave 100% control of soft rot at a concentration of 25 p.p.m., and 100 gallons of solution could be used to treat 9000 lb. of cut seed potatoes without reduction in activity of the dip. Solutions of Agrimycin maintained their activity for 3 days after preparation, but decreased thereafter. Phytomycin (streptomycin nitrate) was less effective after repeated use. Despite the value of streptomycin salts in the control of bacterial rot, they did not inhibit decay caused by the fungi *Phoma tuberosa* and *Fusarium* sp. On the contrary, treated seed pieces showed more fungal rot than did controls. From the results of *in vitro* trials with Agrimycin on tuber slices it is suggested that the antibiotic either increases the susceptibility of the potato or stimulates the growth of the fungi, for the question of microbial antagonism was eliminated. D.L.

**In vitro development of resistance to an antibiotic by two plant pathogenic bacteria.** J. Carmona-Gomez, *Phytopathology*, 1956, **46**, 522–3.

The antibiotic A-6 (a crude sample of a basic antibiotic produced by an unidentified *Streptomyces*) is active *in vitro* against the bean pathogens *Xanthomonas phaseoli* var. *fuscans* and *X. vignicola*. In order to determine whether strains could be developed that were resistant to the antibiotic, the fungi were cultured in nutrient broth with sub-lethal concentrations of the antibiotic. The series were started at concentrations of 0·75 µg./ml. for *X. phaseoli* and 3 µg./ml. for *X. vignicola*. 0·1 ml. of medium taken from the highest concentration at which growth of the bacteria was readily visible was used as inoculum for the next series.

New transfers to higher concentrations were made every 8–10 days for 10 weeks; this allowed for 8 transfers in the case of *X. phaseoli* and 9 for *X. vignicola*. With *X. phaseoli* var. *fuscans* each transfer resulted in growth at progressively higher concentrations of A-6, up to a concentration of 300 µg./ml., which was 400 times greater than that tolerated by the original culture. The increase was not so regular with *X. vignicola*, but the final concentration tolerated was 133 times as much as the original tolerance. It is suggested that these findings may point to the reason why field results sometimes fail to emulate the degree of control given in earlier trials. D.L.

**The inhibitory action of extract of *Capsicum frutescens* on plant virus infections.** C. D. McKeen, *Canad. J. Bot.*, 1956, **34**, 891–903.

Juice expressed from leaves of *Capsicum frutescens*, applied to leaves of cowpea and *Chenopodium hybridum* before their inoculation with a variety of plant viruses, prevented infection of those plants. It was effective to a lesser extent on tobacco varieties and *Physalis peruvians*. When applied after inoculation the juice did not appreciably reduce the number of lesions produced by a virus. The extent to which the juice decreased the number of lesions was dependent only on the plant species inoculated and not on the virus concerned. Juice applied at some distance from the point of inoculation also inhibited lesion formation. The inhibitive component of the pepper juice is probably a protein: it is thermolabile, resists ageing and drying *in vitro*, and does not pass through a cellophane membrane. Nevertheless, the protein component of the juice was less active than the whole raw juice. D.L.

**Influence of aliphatic organic acids and metal ions on numbers of local lesions produced by a tobacco necrosis virus.** R. E. F. Matthews and C. H. Proctor, *J. gen. Microbiol.*, 1956, **14**, 366–70.

Many aliphatic organic acids, when sprayed on the leaves of bean plants, decreased the numbers of local lesions produced by inoculation with a tobacco necrosis virus. Citric and succinic acids were effective only when applied before or during the period of virus establishment. The inhibitory effect of the acids could be annulled by certain metal nitrates. The explanation that the virus requires metal ions for successful establishment and that the acids inhibit this process by decreasing the concentration of available metal ions was not tenable, for preliminary tests with a chelating agent caused no greater decrease in the number of lesions than did citric and succinic acids. D.L.

**The injurious effect of timothy and rye infusions on tobacco seedlings.** L. W. Koch and Z. A. Patrick, *Proc. Canad. phytopath. Soc.*, 1956, (23), 17–18.

In studying the relation of preceding crops to tobacco, experiments were conducted to determine the changes produced by soil-water infusions of timothy and rye on tobacco seedlings. The toxicity of timothy infusions increased for 21 days, when an average of 71% inhibition of respiration was obtained. Rye infusions were most toxic after 10 days, causing 40% inhibition. Autoclaved infusions had little effect on tobacco respiration. Seedlings placed in toxic infusions showed wilting and root discoloration within 24 hours. It was concluded that certain toxic principles are produced during the microbial degradation of timothy and rye residues in the soil. D.L.

**Dalapon for control of grasses on Hawaiian sugar cane lands.** N. S. Hanson, *Down to Earth*, 1956, **12**, (2), 2.

Sodium TCA has been used experimentally to control grass weeds in sugar cane since 1948, and sodium dalapon since 1953. Dalapon has been found to be generally more effective than TCA, and is now used on sugar cane plantations in Hawaii. It is applied as a directed post-emergence spray, and tests have shown that split applications are more effective than large single ones. The maximum rate for one application should be 5 lb. acid equivalent per acre, and the total application to any one crop 10 lb./acre. Experiments have shown that dalapon is most effective when applied in 25–50 gal./acre, and that rain does not have an adverse effect unless it falls within half an hour of spraying. A mixture of 3 lb. 2,4-D sodium salt and 6 lb. sodium dalapon with 5% by volume of a diesel oil emulsion, applied pre-emergence, gave good results against broadleaf and grass weeds. The use of dalapon and similar herbicides has given rise to an increase in tolerant broadleaf weeds, and tests with an emulsion of dalapon with aromatic oil are in progress to overcome this. R.A.U.

**Preliminary screening tests of amino acid derivatives of 2-(2′,4′-dichlorophenoxy) propionic acid.** C. F. Krewson and others, *J. agric. Fd Chem.*, 1956, **4**, 690–3.

Details are given of the synthesis and plant growth activity of a series of D-, L-, and DL- forms of the amino acid derivatives of 2-(2′,4′-dichlorophenoxy) propionic acid (2,4-DP). The lanolin paste assay method was used to test the effect of the compounds on sunflower and cucumber, while the coated sand method was employed in experiments on barley and maize. Information is given on the effect on stem curvature, growth inhibition, epinasty, formative effects and cell proliferation. There was almost complete lack of growth-regulating properties in the D-amino acid derivatives of 2,4-DP during the two-week test period, but most of the L- and DL- isomers were shown to possess moderate to high activity. In general the activity of all the D-, L-, and DL- compounds of this series was lower than that previously reported for other series of halogenated phenoxy acids. It is stated, however, that the compounds warrant further study because of their herbicidal potentialities. E.M.A.

**Chemical control of weeds in sugar beet.** C. Parker, *Brit. Sugar Beet Rev.*, 1956, **24**, 161–4.

In 65 commercial sprayings of sugar beet in 1955 with sodium nitrate, 20% were highly successful, 40% were satisfactory and 40% failed to increase crop yields. Good results depended on a 24-hour period of dry weather following spraying, rapidly growing weeds, and high-volume applications of the chemical. Dressing the seedbed with a nitrogenous fertilizer, in addition to treating the crop with nitrate spray, may result in excessive nitrogen in the soil, which can seriously reduce the sugar content of the beet, particularly in dry seasons. The alternative pre-emergence herbicide, PCP in oil, which can be applied in medium volume, gives better control of wild radish (*Raphanus raphanistrum*) and charlock (*Sinapis arvensis*), but its successful use is restricted by the very careful timing of the spray application that is necessary. Recent trials for wild oat control have shown that IPC gives variable results, and on some soils causes serious crop damage. Disc harrowing greatly improves control. TCA has given more reliable results with less risk to the crop. M.M.W.

## ANIMAL HUSBANDRY

**Controlled grazing for fattening cattle.** A. E. Parkinson, *Scot. Agric.*, 1956, **36**, 62–4.

Initial trials in Aberdeenshire from 1949 to 1953 indicated that, contrary to popular belief, controlled grazing was not detrimental to the fattening of beef cattle: the heavier manuring (necessitated by controlled grazing techniques) gave earlier grazing and increased stocking, and this resulted in greater output of beef per acre over the season. In 1954 and 1955 investigations were continued in greater detail, and these reveal increases in the number of grazing days, in the average daily gain, in the average gain per acre, and net returns per acre by use of controlled grazing for fattening cattle. E.M.A.

**Antibiotics for the prevention of bloat in cattle grazing ladino clover.** B. F. Barrentine, C. B. Shawver and L. W. Williams, *J. Anim. Sci.*, 1956, **15**, 440–6.

In a research project at the Mississippi Agricultural Experiment Station to study the value of antibiotics in the prevention of bloat, yearling steers, prone to bloat on clover, were allowed to graze on ladino clover for 1½ hours in the morning and in the afternoon and dosed with antibiotics after the morning feed. Bloat was suppressed for 2½ and 7 days in two tests with a 1 g. dosage of aureomycin, and for 6, 7 and 10 days in three tests with 1 g. terramycin; but severe diarrhoea resulted in all instances. It was not suppressed by aureomycin at 100 or 300 mg., by terramycin at 50–100 mg., or by bacitracin or streptomycin, each at 300 mg. Procaine penicillin at 1 g. stopped bloating in three steers for 6, 7 and 10 days, but there was severe diarrhoea in all animals; at 100 mg. dosage two steers stopped bloating for 2½ days without showing diarrhoea; 50 mg. stopped bloating in two steers for 1½ and 2½ days; 25 mg. was not effective. (Numbers of steers used in each experiment were not stated.) Work in a second year confirmed that yearling steers could be protected from bloating for 1½–3 days by single doses of 50 mg. of procaine penicillin. Two-year-old steers required 75 mg. for the same effect. Potassium penicillin was just as effective as procaine penicillin. Results with steers kept in pens and fed on fresh-cut clover morning and evening were the same as those obtained in steers at pasture. The anti-bloating action of penicillin was slow, since steers usually bloated after the afternoon feed but did not bloat on the next day. This held good for all doses up to 1 g. Support is given to the theory that bloat is caused by the activity of micro-organisms in the rumen and that these micro-organisms are more susceptible to penicillin than to the other antibiotics. J.T.E.

**Toxicological problems in the use of systemic insecticides for livestock.** R. D. Radeleff and G. T. Woodward, *J. econ. Ent.*, 1956, **49**, 89–91.

The U.S. Department of Agriculture has carried out trials with systemic insecticides on animals for the past three years. Apart from questions of obvious toxicity, other factors have been noted and they must be resolved before the internal chemotherapy of ectoparasites can be considered commercially. The effect of organophosphorus compounds on cholinesterase did not always give a reliable indication of toxicity, for reserves of the enzyme in an individual could be five times greater than in another of the same species. Cholinesterase reserves declined by as much as 40% when cattle and sheep were transferred from pastures to yards. Complete absorption of an injected insecticide could take several months, and when stored in the body fats the toxicant or its metabolites was not released until the fat depots became depleted; therefore a compound with a low rate of elimination administered in the spring would not affect parasites until late autumn. When the release was more rapid than the elimination, poisoning occurred. The volume of liquid to be injected provided a practical problem. Lindane was not toxic to cattle at 50 mg./kg. when administered as a 5% solution in arachis oil, but when the concentration was doubled to reduce the volume (250–500 ml. for an adult cow) the same dosage was toxic. The route of administration also affected dosage; lindane and aldrin were lethal at 25 mg./kg. when given orally although harmless subcutaneously. Problems requiring fullest study are the effects of insecticides on enzyme systems in the tissues and digestive tract, their effects on the intestinal flora, the presence of residues at slaughter, and effects on fertility. D.L.

**The effect of some chlorinated hydrocarbons as systemic acaricides against the cattle tick, *Boophilus microplus* (Canestrini).** W. J. Roulston, *Aust. J. agric. Res.*, 1956, 7, 608–24.

Although the technique cannot yet be recommended for general use, the experimental subcutaneous injection of cattle with lindane, dieldrin, and aldrin solutions in arachis oil, at a rate of 25 mg. toxicant/kg. body weight, produced marked effects on infestations of *Boophilus microplus.* Initial infestations were reduced, but many ticks continued to develop to maturity; seed ticks were, however, unable to establish themselves. The average period of total protection was from the 7th to the 22nd day with lindane, from the 12th day to the 25th with dieldrin, and from the 16th day to the 27th with aldrin. Beasts injected with lindane showed their first persistent reinfestation of young ticks about six weeks after injection; aldrin gave protection for more than 80 days. Toxaphene, diazinon, malathion, isodrin, endrin, and Dipterex produced no systemic effects. Systemic control of ticks over the whole body region was also obtained from skin applications of lindane and dieldrin (but not with aldrin) made on the neck. D.L.

**A new method of treatment for sheep infested with the larvae of the sheep nasal-fly, *Oestrus ovis.* L., in the Union of South Africa.** R. du Toit and O. G. H. Fieldler, *Onderstepoort J. vet. Res.*, 1956, 27, 67–75.

The authors have developed a new preparation based on γ-BHC for control of the sheep nostril fly. The recipe, in parts by volume, is: benzol, 12·5; acetone, 12·5; paraffin (kerosene), 10·0; sulphonated castor oil (technical), 57·0; Triton X 100, 2·0; oleic acid (technical), 6·0. Lindane is included at 4 g. per 100 cm$^3$. This preparation was tested by many veterinarians in South Africa and gave very good results in 2865 severely affected sheep. The nasal mucoid secretions ceased in the vast majority of cases within 9–14 days, and the animals showed signs of loss of their nasal bots by feeding normally again and by improvement in condition. A small proportion of the sheep did not respond and were treated a second time after an interval of 2–3 weeks, and nearly all of them responded to this. For ewes with suckling lambs treatment interferes with mothering, and it should be delayed until after weaning. In toxicity tests with the above preparation containing 6% of lindane, doses of 2 cm. were injected into each nostril of 12 lambs aged from one day to 7 months. Four lambs under one week old showed muscular tremors 20–30 minutes after injection and 3 of them died. The others showed no toxic effects. It is advised that flocks of sheep troubled with nasal bot should be treated three times at intervals of 3–4 weeks to eliminate the successive generations of the nostril fly by treatment of the larvae in the sheep. J.T.E.

**An experimental study of certain aspects of the epidemiology of parasitic bronchitis in adult cattle.** J. F. Michel and R. E. Mackenzie, *Emp. J. exp. Agric.*, 1956, **24**, 61–74.

In experiments carried out in 1952, 1953 and 1954 near Cambridge cattle aged 6–30 months were exposed to infection from calves artificially infected with *Dictyocaulus viviparus* larvae under conditions of set stocking and rotational grazing, with under- and over-stocking. Faecal larval counts were determined twice a month. In all three experiments there was no evidence of a continued rise in the infestations either in the animals or on the herbage; in the second and third experiments the faecal larval counts rose rapidly to a peak and as rapidly fell, and it appeared that by the time the rate of herbage infestation rose the cattle had become refractory to re-infection. Transmission coefficients, corrected for differences in infection deposited by the carrier calves and in density of stocking, apparently depended on climatic and other factors; in 1953 set stocking at high rate > rotational grazing with low rate of stocking > set stocking at low rate > rotational grazing with high rate of stocking, whereas in 1954 rotational grazing with low rate of stocking > set stocking at low rate > rotational grazing with high rate of stocking > set stocking at high rate. S.F.A.

**Parasitisme interne du mouton en zone sahelienne. Oesophagostomose nodulaire en particulier. (Internal parasites of sheep in French Equatorial Africa, with special reference to nodular worm disease.)** M. Graber and P. Receveur, *Rev. Elev. Med. vet. Pays trop.*, 1956, **9**, (1), 5–20.

The authors carried out a survey of worm parasites of sheep in the Tchad region, and they give lists of trematodes, cestodes and nematodes identified, together with figures showing the extent of parasitism. A detailed account is given of the nodular worm and the symptoms and lesions caused by it. The following is said about treatment. Phenothiazine in dosage of 0·2 g./kg. given twice on consecutive days removes many nematodes, including *Strongyloides papillosus.* For *Gaigeria pachyscelis* a minimum dose of 0·5 g./kg. is required. Nodular worms require even more. To find out the minimal effective dosage, sheep were treated with 0·2–1·0 g./kg., the numbers of adult nodular worms removed were counted and the numbers still present in the intestine 5–6 days after treatment. The elimination of 75% of the worms is regarded as evidence of satisfactory treatment. This figure was never secured by a dose of 0·2 g./kg. and was only secured in one quarter of the test sheep by dosage up to 0·5 g./kg. A dose of 0·8 g./kg. secured this effect in 71% of the test sheep. (Numbers of treated sheep were not given.) From the above results the authors state the effective dosage of phenothiazine against nodular worms at 0·8 g./kg. twice at an interval of 24 hours. This high dose is well tolerated nine times out of ten, both by young and adult sheep. Pregnant and lactating ewes should not be treated. Advice is given as to the best time for treatment and about supporting measures to eradicate nodular worms. J.T.E.

**Recherches sur le traitement spécifique de la *Dicrocoeliose ovine.* (Research on the specific treatment of *Dicrocoeliose ovine.*)** J. Guihon, *Rec. Med. Vet.*, 1956, **132**, 733–49.

The author tested numerous chemical compounds for activity against the lancet fluke in sheep. Sheep which were presumably naturally infested were treated after 12–24 hours' fasting and the effects were assessed by repeated coprological examinations and, finally, by post-mortem examination. A large table gives the names of the drugs or mixtures of drugs, the numbers of sheep treated with each test substance, the dosage and administration route, the toxic effect on the sheep and the effect of treatment upon the flukes and their egg output. No compound was found which was at the same time effective and non-toxic. All the established anthelmintic drugs were tested and also triphenyl methanes and other dyes, antimony compounds and bile stimulants. J.T.E.

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